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Editorial

An engagement among scientists, society at large, and the political establishment has always been a matter of serious concern with regard to the respective roles of, and expectations from, each other. Due to the rapid developments in science, and more so in technology, during the past 100 years or so, an active interaction among all stakeholders has become even more crucial under changing societal dynamics. Although there are some fora for discussions on specific issues related to science and society, there has been no over-arching academic platform where a general and inclusive dialogue about science, society and scientists could be held. In this context, the Indian Academy of Sciences, Bengaluru, came up with a unique endeavour to start an online journal called “Dialogue: Science, Scientists, and Society” with an aim to provide a forum for academic debates on issues related to practice of science, communication of science, and impact of science on society, and vice versa, in particular, and other issues such as gender in science, culture of science, science policy, education and funding etc. in general. Dialogue was envisaged to be an academic, peer-reviewed journal. It was also decided to start a web discussion platform, called Confluence, to have more informal, though editorially moderated, interactions among the stakeholders. We have now completed one year and have made substantial progress towards achieving the stated aims. Over 100 items have been published in Dialogue and Confluence on contemporary issues related to science and society.

Another initiative of Dialogue has been to engage in public outreach activities. Several such activities, some exclusively by the Academy and others in association with other academic or non-governmental institutions, have been conducted in Bengaluru, Delhi, Pune, Chennai etc. in the form of lectures, demonstrations, interaction workshops, etc.

In the coming years, we hope to make these platforms even more active in the areas of publications as well as outreach activities in smaller cities and in different Indian languages. We solicit an active participation of all stakeholders.

Mewa Singh
Chief Editor
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INTERVIEW

Standing Conventional Wisdom on its Head

An interview with RAGHAVENDRA GADAGKAR by HARI SRIDHAR.

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Hari Sridhar (HS): The motivation for this interview is the talk you gave in Young Ecologists Talk and Interact (YETI) conference in 2009, which was in the form of advice to young ecologists on how, you think, science should be done. One of the points you made that stayed with me for long after the talk was about making the transition from being a student to doing research – from taking courses to doing research – which you said involves a process of ‘unlearning’. Can you tell us a little more about what form you think this ‘unlearning’ should take?

Raghavendra Gadagkar (RG): One of the points I emphasised was how to make the transition from taking courses and passing exams to doing research and making discoveries. And I said that if you want to make this transition, you really have to turn around 180 degrees because the optimum strategy for being successful in taking courses and passing exams is quite the opposite – not just different but the opposite – of the optimum strategy for making discoveries. For example, if one wants to take courses and pass exams then it makes sense for the person to be in a place where one is comfortable. If you have to write a test and you know that you will be given four questions and you have to answer any two, it makes sense for you to focus on the two where you are most comfortable. It doesn’t make sense for you to say: I know the answers to these two, I don’t know the other two, but I am going to try and answer those for which I do not know the answer. But if you are doing research that is exactly what you have to do. It doesn’t make any sense to say I know this, therefore, I am going to work in this area. You have to work on what you don’t know. You have to move away from the comfort zone of knowledge and familiarity and position yourself in the zone of discomfort, comprising of ignorance and unfamiliarity. In other words, you must enjoy feeling stupid. If
you say that it’s frustrating because you don’t know what’s going on then you are probably not cut out for research. Also, for taking courses and passing exams you often have to focus on storing information and recalling at the right time, which is not at all useful for research. Now that is easy to say – most people will agree with that – but the problem is much deeper and psychological. Our entire social structure is built on great prestige for knowing facts and a great shame for not knowing facts. Somehow, thinking is not part of our social culture. I guess that’s because for most things you don’t have to think - somebody has thought it for you. You just have to know what it is. In research obviously, that doesn’t work. You have to do exactly the opposite and you have to learn how to think \textit{de novo}.

There is another problem with doing this, which is that you need a certain kind of mental energy to absorb facts and recall them and a very different kind to be able to think through something. These two are not the same. You can train yourself either to do this or to do that. Seldom can you do both; there is a trade-off between these two. Take the example of people who become millionaires after answering all those questions on quizzes – they are really optimised so that they can store and recall information efficiently. They don’t need to think. And that’s a good thing when you are taking exams and doing courses. In fact, all said and done, in most exams, thinking is still a minor thing. In fact, even if it is required, you also need to remember lots of facts in order to do the thinking. In research, you don’t have any of those problems. If you want to optimise yourself for thinking, then you have to tell yourself that you don’t need to carry the facts with you. You can get them whenever you want. If you clutter your table with all the supplies you have in your house, you can’t cook. So all the items should be on their shelves and you take them out whenever you want them and then put them back. You should have space to cook. The equivalent shelf for research is your library or the internet. Take it, use it, but keep space in your brain to do the thinking. But in order to do that, you must get over this feeling of pride in knowing facts and feeling ashamed of not knowing them. I tell my students: do not be proud that you know something and do not be embarrassed that you don’t know something. In fact, I go to the extent of saying that those of you who already know the facts are the unfortunate people, because once you know a fact it’s very difficult for you to actually derive it \textit{de novo}. It’s very hard for you to walk that path. Your mind refuses to do that. Also, it’s very boring. Imagine somebody gave you a really nice mystery novel and says: I recommend you read it and by the way, that’s the guy who actually committed the murder. You will not want to read that book. You will want to read that book because you want to know who the killer is. That’s what drives you to read the book.

So, I often tell my students that I won’t give them facts but I will teach them how to think. But in order to do that, I have to find a topic where they don’t know the answers already. And I must confess that it is becoming increasingly difficult to do so. Due to the internet, now students know everything. They don’t know how to get there but they all have the final answers. So I have to find something that they haven’t heard of. And then what happens in a typical class is there are a few students who know it all and are eager to answer and I have to keep them down. I always look for that student who doesn’t know the answer so that I can demonstrate through that student, to the others, how to find the answer \textit{de novo}. Sometimes it gets very funny. A student once told me: There’s something wrong with you. Yesterday I knew the answer and you didn’t let me answer. Today I don’t know the answer.
and you are harassing me. But that is exactly the point. It is by ‘harassing’ the student who
doesn’t know the answer that you can demonstrate how to find the answer de novo, to the
unfortunate ones who already know the answers. So I keep telling them that when I am
‘harassing’ this student the others can’t go to sleep. This student is the altruist who is going to
help you learn how to walk this path that you are no longer capable of walking because you
already know the answer. What does that mean? That means you shouldn’t read too much
because you have closed the doors for everything that you have read and got the final answer
for. Even as an experiment in learning how to think, that territory is no longer available to
you. So there is an optimum amount of reading that you should do. And your reading, as far as
possible, should be around or outside your field. If you want to do research, you shouldn’t read
on too much in your topic, but around your topic, so that you can bring in new perspectives to
bear on the topic. If you read all there is to read on your topic you will probably do the same
thing that other people have done. It is very hard to think of new ideas. Every idea you can
think of has already been thought of.

But even more than that, the real problem I think is that, given the way our brains are
constructed, it’s much easier for us to master the art of remembering - of inputting and
outputting facts. I think our brains are not constructed to think very much, and another big
problem in thinking is what I call mental laziness. Very quickly you are lazy to think further.
Let me take an example. In an exam, a student is copying from his neighbour. Now, Step 1 is
that the student knows that he is copying. Step 2 is that the student knows that I have seen
him copying. Step 3 is that the student knows that I know that he knows that I have seen him
copying. These are three different things if you think about it. If the student has copied and
nothing else has happened that has one consequence. If the student has copied and I have seen
him that has another consequence – I can punish him but he doesn’t know that. If he knows
that I know, he will stop copying, otherwise; he will continue to copy – do you see these are
three different things? Now with some difficulty, we can manage these three levels. But you
can take it to a fourth level – do I know that the student knows that I have seen him copying?
If I know that the student knows, then I know that he is going to stop copying and therefore I
must do something else. Now you can take this to infinite steps but try doing this and your
mind gives up very quickly. Three is difficult, four is about the limit, and after that, it’s all
muddled up, because of mental laziness. And that is what we need to avoid. But that’s not a
problem when you are taking courses and passing exams. So doing research is a very different
game. Unfortunately, we do not train people to do research. We mainly train people to take
courses and pass exams.

**HS:** You say one shouldn’t read too much. Is there the danger of going too much in
that direction? One would imagine that to be able to come up with new ideas, to be
creative, one needs to be able to make connections between facts, and those
connections might not happen unless one has those facts in one’s head.

**RG:** I have the following model. I make the assumption that anybody who wants to do
research is a reasonably intelligent person who will read X amount of stuff in a 24 hour
period. All I’m saying is that as large a fraction of that X as possible should be outside and
around your field; outside your problem. I am not saying you shouldn’t read. Then, of course,
you are not able to think. But as far as possible the reading should be outside. In research, you
don’t want to do what others have already done. You want to do something different. You
want to come up with a different theory, a different answer. In research, getting a correct
answer is not important, getting a logical answer is important. You don’t know which answer
is correct. Ultimately, if all these hypotheses are put to test then something turns out to be
correct. We don’t reward people for being correct, we reward people for saying something
new. For doing something that’s creative. Therefore, the best strategy is to do what others are
not doing. And you can take for granted that most people are working very close to the centre
of their problem. So the further you go with your reading, the more are the chances that you
will have a different perspective from others. And that’s really what matters. So it’s not the
absolute amount of reading, but the distance of your reading from the actual centre of your
problem that matters.

HS: You mentioned in your talk that people who are good at doing courses might not
be good at doing research, and that there is unlikely to be a strong correlation
between the two...

RG: Let me refine that a little bit. I think there is a trade-off between doing well in courses and
doing well in research. But I wouldn’t say that people who do well in courses will not do well
in research. I don’t think people are fixed. If you have trained yourself to do well in courses,
but are unwilling to unlearn, then you won’t do well in research. But if you are willing to
unlearn and now have a new strategy then you can do quite well. There is a trade-off between
the strategy to do well in courses and the strategy for doing good research, but it is entirely
possible that the same person will be able to change the strategy. So this has relevance to the
question you were asking about how one should pick candidates for a research programme. If
there was a simple one-to-one correlation - a person who is good in taking courses and
passing exams will not be good in research - then, of course, it is very easy. You give an exam
based on courses and whoever fails you take for research! But it doesn’t work like that
because some people are able to change and some people are not able to change. Also, some
people are so intelligent that they will be able to optimise the strategy required for passing
courses but then shift to the strategy to do good research. That is what makes it much harder
to select people. You can’t simply say I will take the people with the lowest marks. That’s not
going to work because the people with the lowest marks might not be capable of doing either.
People with the highest marks maybe capable of doing both, but also may not be. And then
there are people who are very poor in taking courses and passing exams but actually very
good in research. So you have to work very hard at selecting people. And the one way to do
this is to actually put them to a test in thinking during your selection process

HS: Isn’t that difficult given the number of people who apply?

RG: Not so difficult. Ideally, take them outside their zone of comfort and see whether they can
think. It is not so difficult. In 30 minutes you can judge whether a person is capable of
thinking. It depends on how you spend those 30 minutes. What we typically do is for 25 out of
30 minutes we ask them for the facts they know, and for barely 5 minutes we ask them to think – that is the problem.

**HS:** But what you are suggesting is possible only with a smaller subset of shortlisted candidates. How do we do the first step when a large number of people apply?

**RG:** I think you need a minimum of 30 minutes, ideally an hour. So if you are willing to spend 50 hours you can only have 50 to 100 candidates. But you will have to have some other method to bring the first set of applicants down to 50 or 100. I don’t think there is any way of getting around that. But of course, you can design written exams that test thinking abilities rather than recalling of facts.

**HS:** You said that while in an exam it pays to choose the easiest question, in research it might be best to choose the one we know the least about. I would like to ask you about your own strategy when it comes to choosing a research question. What makes a particular topic worth pursuing to you?

**RG:** The answer should not be obvious, nor should it be so obvious that you will find the answer rather quickly! Only then it’s challenging, otherwise, it’s not. Having said that, I must also say that in real life, for my own research - this takes us off into a completely different territory, so we won’t go there just yet, but I’ll just say - I have chosen to understand everything humanly possible about one species of social wasp. That is my decision. That’s what I want to do. So in trying to fulfil that decision, I’m not always in the position of saying whether I shall answer this question or that. I need to answer all or most questions in order to go to the next level. So in real life, I don’t always discard questions because they are easy or obvious. I do them quickly. But I find it much more challenging to address questions where the answer is not so obvious. Often there are lots of little, not so interesting, questions that you have to answer to be in a position to get to the big, more interesting and more challenging questions.

**HS:** You have been working with this one species for over 30 years. Right from the beginning did you know that this was going to be a long-term research interest?

**RG:** Not in the beginning, but very soon it became obvious. See, I had been playing with this species for a long time, but I will say that I seriously started working on this species roughly in the year 1980. And in 5 years it was clear to me that there is enough gold here that one can spend one’s whole life in it. It took about 5 years, not longer than that.

**HS:** Going even further back, when did you first realise that you were interested in doing research?

**RG:** Oh! That was very long ago. I probably didn’t know the meaning of research at the time that I realized that this is what I wanted to do. I mean I was curious and interested in science. But again there was this problem: I never thought that science has to be done in exclusion of
other things. It never occurred to me that if I did science I couldn’t do literature. I found it very funny. In those days, you had to choose in 8th standard - Science stream, Arts stream or Commerce stream. I was completely at a loss because the two subjects that I was extremely interested in, and which I thought I will pursue for the rest of my life, were Science and Hindi literature. My Hindi teacher thought I was born to do a Masters in Hindi and my Science teacher thought I was born to do a PhD in Science. I thought I was born to do both! But I had to very reluctantly drop my dream of studying Hindi at that stage. And then when I came to study Biology, they said choose between Maths or Biology! So I had to drop Maths. And then later they asked me to choose between Molecular Biology or Animal behaviour. I said I want to do both. They said you can’t do both, you can only do one. The higher I went, the more doors closed – very strange indeed.

HS: Going back to your own philosophy when it comes to choosing research questions – the pieces of the puzzle, not the big questions – do considerations such as doability, money required, technology required, etc., play a role in your choice?

RG: Absolutely. And I think the biggest mistake that people make is they do not do what I call a feasibility analysis. You are a postdoc in National Institutes of Health (NIH), you are working on a problem, and you bring a little piece of that problem and come and join some place in India and want to do the same thing. You are not worried about whether you can do the same thing with the same level of competitiveness; you do not worry enough about what you will need, how much money you will need, what kind of facilities you will need. Nobody worries about these matters, or at least not enough. They start-off and then they complain. I think that’s the biggest problem. What you need to do is choose a research problem where the rate-limiting step is only your intelligence. That’s what should actually finally stop you, not money, facilities or anything else. If you choose a problem where the rate-limiting step is your intelligence, then you will not be frustrated. You can say this is all I could do because that’s all the brain I have. Whereas if you say: oh!, I could have done so much better if I had more money or if I had that equipment, that’s a ready-made excuse to not do very well.

But again, one has to qualify this. In the real world, the time when you should adopt this philosophy is not when you are a PhD student; instead, it’s when you become an independent scientist. In most cases, I think a PhD programme is best treated as an apprenticeship. I will give you an example. A friend of mine once sent me a message saying that he went to one of the branches of the National Museum of Natural History and met a young person who was very interested in spiders. The person said that nobody was helping her and he asked her to write to me. So she wrote to me and said that she had some very interesting ideas for spider research but was very frustrated because nobody was able to help her. I told her I didn’t know too much about spiders, but she could come and visit us for a week. So she came for a week and outlined her research plan and then said that it’s so frustrating that nobody is working on this! I said you should be frustrated if somebody is already working on your idea. If nobody is working on your idea, that’s nice! I told her she might be planning to be someone’s assistant to work on the problem of her choice, but why should she be? I told her that she should safeguard her idea and acquire all the skills that she needs to help her solve the problem later, when she is an independent scientist. Your PhD or postdoc is often only meant for you to
acquire the toolkits that you need for your research career. You don’t necessarily have to do your best work when you are a student or a postdoc. And in today’s modern science where you need lots of techniques and skills to be able to tackle a cutting-edge problem, you should use your PhD and postdoc to equip yourself with those skills. But what most people do is that they either hope to do Nobel prize-winning work during their PhD, or they get latched on to a problem forever that ideally should only be used for training. For instance, if you want to come to my laboratory and learn a technique, then you will have to work on my problem. But then, you should not get stuck with my problem and spend the rest of your life on my problem and forget your own problem. So one must learn how to use the time meant for PhD and postdoc, effectively. I once had to tell my student- don’t try to get a Nobel Prize for your PhD work, because most likely you will have to share it with me! If you wait, you might get it by yourself!

HS: Did these considerations – the money required, the technology required, etc., – go into your decision to work on Ropalidia?

RG: Absolutely! It was clear to me that the rate-limiting step should be my brain. And until today that is the rate-limiting step. In the beginning, I took a conscious decision that I am going to create a situation where the rate-limiting step, not for quantity but for the quality of my work, would be my ability to use my brain. Not anything else. So there’s no excuse if you fail, otherwise, you always have a readymade excuse even before you start. People say: oh! but he is in Harvard; you can’t expect me to do as well as him. You start with the assumption that you can’t do as well as him. For me, there is no excuse in the world I can give why anybody else in any part of the world should be able to do this better than me. I can’t think of an excuse, except that I didn’t think of it or am not capable of doing it.

It also depends on where you are. Of course, if you end up in NIH you can choose different problems, but even there you must make sure that the rate-limiting step is your brain and not how much money you can get. You may get 10,000 dollars or 10 million dollars. The trouble with scientists often is, instead of saying: you tell me how much money I can get and I will think of a creative scientific problem for that money, they say: you tell me how much money you can give me and I will find a problem for which that money is not enough! I believe that you can do creative work at any level of facilities or money or whatever. Problems will change, but not the creativity.

HS: But there are external forces that make people use the approaches/technologies that are in fashion, e.g., the pressure to use molecular approaches in ecology today?

RG: That’s correct. But I would put 10% of the blame on the people who create the pressure and 90% on the person who succumbs to the pressure. I would not absolve people who don’t blame the individual but rather the pressure. What efforts do people make not to succumb to pressure? I think we do very little to avoid doing what we don’t like to do. We immediately succumb to pressure. Often we succumb to imagined pressure. And even if it is real pressure we do precious little to fight the system. So I’m not convinced by this argument.
What have people done to fight the system? Very little indeed. Whether it is the pressure to use the latest technology for the sake of using it, to publish in *Nature* whether or not your work is good enough; or to have a collaboration with some famous person whether or not it is required. All this pressure is real. But I have not seen people fight it enough. I have seen people succumb to the pressure too easily, and once they succumb, they want the rest of the world to believe that it is not possible to resist the pressure. So they create this myth and the pressure builds up. It’s a self-fulfilling prophecy.

In fact, it is probably nice that there is this pressure on people to do wrong things which leads me to fight the wrong and be different from others. After all, what is the route to success? Doing what other people have not done, not succumbing to pressure is, in fact, the route to success. You should not succumb to pressure and become like everybody else. Your goal is not just to become an assistant professor, but to be different from others. Ninety percent of the people who are assistant professors become associate professors. If that’s all your goal is, then there is no problem. But that should not be your goal. People complain that it is the system, it is the society, it is the peer pressure, which makes us do all of this. I don’t buy any of it. I’m extremely sceptical of it. I rarely come across people who resist pressure. People always succumb to pressure and they complain. I want to see more examples of people who resist pressure.

**HS:** I want to talk about another kind of pressure – the pressure to publish in high-impact journals. How do you decide where to send the papers you write?

**RG:** There are only two things that matter to me. One is, as far as possible, it should go to the audience I would like to reach. Today, that is becoming less important because you put it on your website and people will see it. So what is the most important consideration? It should get published, it should not get rejected, which is the opposite of a typical strategy adopted by the scientists today. The typical strategy is, no matter what one writes, one first sends it to *Nature*. When it gets rejected, one sends it to *Science*. It gets rejected then one sends it to *PNAS*. And then it will trickle down after 3–6 rejections till it finally finds its level. This is what people do. This is hugely wasteful for everybody. The first problem is that the top journals like *Nature* get all the papers in the world! So they have to reject some 99%. It’s a huge waste of everybody’s time. In fact I actually know people who say: I sent a paper to this journal and it got accepted. What a shame, I should have sent it to a higher journal! This is the world we live in - completely crazy! I would like to send my paper to a journal where it has the highest chance of getting accepted. Now if you want to increase that probability what do you do? You send it one step below what you think the paper deserves! I will tell you a story about one journal. In this journal they reject whatever they don’t like, but of the things they like they publish a few and for the others they say: this is not good enough for our journal but we have a sister (step-sister?) journal which we can send it to. If you say yes, it most likely will get published there. I was surprised by this because I felt how can that journal tolerate this? That you are the trash basket for the bigger journal. So I met the editor of that journal and asked him. But he said no, it’s so easy for us because we get papers that are reasonably good and that have already been refereed and we just publish them. Then I told him who I was and he said: Ah, you are one of the few guys who send their papers directly to us. In the long run does it really matter? The
idea in your paper is what matters. Think of what might happen a hundred years from now. People will not look at your paper because it is published in *Nature* or in *Science*, but for the idea it contains. Can anything be more stupid than judging the quality of work depending on where it’s published? Can you think of anything more absurd? Recently I heard this very interesting statement. Somebody said “just because our paper is published in *Nature* doesn’t mean it’s wrong”? But I don’t even blame *Nature*. They are doing the right thing from their own point of view. We have sold our souls to journal editors. How did we let this happen?

I will tell you another story: some years ago I was invited to give a talk in a University in the USA. Before my talk, they wrote to me asking if I had some free time and whether I could meet some of the faculties in the life sciences department. They gave me a list. Is there anyone in the list who you wish to schedule a one-on-one meeting with? I looked at the list and found that most of them were my friends. So I wrote back to them saying that I know all of them and I can’t choose any one or two for having one-on-one meetings with. Instead, give me a one-on-many meeting with your students. They said this is great and all the PhD students and postdocs of the department were scheduled to meet me for 2 hours over a pizza lunch. So I met the students and discussed about the issues around research and publications. Some of them said: it’s very easy for you to say all these, but we are students. We have to succumb to the pressure of publishing in high impact journals because otherwise, we won’t get jobs. So I said I agree with you, you are absolutely right. I said: for advancing your career you do whatever you want, do all the ‘wrong’ things that the system wants you to do, no problem. But very soon you will be sitting on the other side of the table to judge others. I am only asking you to make this resolve that you will not judge anyone by the journal in which he or she has published, by the impact factor, or by the H-index. If you agree to do this the world will change in 10 years. But the world has not changed because you will begin to believe that what you have done by succumbing to pressure, is the correct thing to do. So when you say you know this is wrong but you are doing it for survival, you slowly begin to believe that this is the correct thing and you make sure everybody else does it. Otherwise, the world should have changed by now. So this idea of saying I do it because I can’t help it, is actually not true.

**HS:** But, today, do you think it is even possible to come up with ways of judging huge numbers of applicants for jobs/fellowships/PhD, etc., without resorting to convenient metrics like H-index or number of publications?

**RG:** Absolutely. Why are you imagining that there are always hundreds of applicants? There are hundreds of applications sometimes, when we may be forced to use unsatisfactory metrics. But the tendency always is to think of one unlikely scenario where you have no choice but to do something, and, with that, hide all the hundreds of scenarios where we can do much better. We say how else can the president of a large university with 3000 faculties decide who is good? Why should he decide who is good? He should not. He should depend on many others. If I have to judge people I will read the papers of those whose work I understand. For those whose work I don’t understand, I will get the help of trusted colleagues who understand. There will be at least one person in this world who will be able to read and judge another person. And if there is nobody, then you take that candidate anyway - he must be good if
there is nobody in the world who can judge him. So we don’t have to imagine extreme situations all the time.

There was a time, 20 years ago, when I used to spend some days in selection committees for choosing people for one thing or another - a prize, a fellowship, a job. In every such committee somebody would come and give us a very nice description of the work of the applicants/nominees before we made our decision – these were really like a series of mini-seminars on a wide range of topics. It was a most interesting and most satisfying experience. But now, in the same selection committees, everybody comes and talks only about the number of publications, citations and H-index. I hear this for hours or days and I’m bored to death. We just don’t seem to read anymore. This is a fact of life. Because these metrics are available, we have stopped reading. It’s absurd. The world in which we live is completely absurd. And I think we are not realizing it.

HS: So when you find yourself in a position where you have to judge the work of your peers or students, what do you look for?

RG: If the judgement is to be based on reading, then I read. And when I don’t understand I ask. I ask other people to read and explain it to me. I do not judge based on number of papers or citations or impact factors. I judge on the content and I try to understand the content and I try to compare the content. That’s baseline for me. I am really impressed by a piece of work if I feel: Why didn’t I think of it? That’s my ultimate test. A lot of things are boring. Anybody can do it. If I had to pick one out of 10 people then I would apply that criteria. In addition, I would say: What would have happened if this paper was not published? Would it have made a difference to the field? You can always say all data is necessary, and, in the future who knows somebody may need it. Fine, but suppose I want to give a prize to one out of 10 people, I would certainly apply this kind of criteria. What would have happened if this paper had not been published? Would the field have changed? Would the field have slowed down? And do I feel that I wish I had done this piece of work? Now if you say that my method is subjective, of course it is. That is why we should keep changing committees frequently so that all manner of subjective assessments by diverse sets of people will even out.

HS: What about a piece of work makes you feel: why didn’t I think of that? Does it depend on how novel the work is, does it depend on risk-taking, does it depend on being correct?

RG: It definitely doesn’t depend just on being correct. It is cleverness. There is a clever way to do things and there are dull ways to do things. For example, let’s say you take a well-known technique in one field and apply it to another field in an extremely exciting way. If you apply it in the same field there is nothing so great about it. Sometimes when I see work which is highly-valued or published in *Nature*, I ask myself: why did *this* person and not *that* person do this? Often the answer is: Because only this person had access to this data, or this population, or that instrument. That is not so great. It’s not surprising that this person did it. I am excited
by a piece of work that anybody could have done, in principle, but only one person did it. That’s the kind of work that makes me think: why didn’t I think of that?

HS: Could you name a few pieces of work or scientists whose work provokes that reaction in you?

RG: I could probably do it, but I prefer to give you a slightly different answer to the same question. This is something I have thought through and written about. When I was an undergrad, I was absolutely fascinated both with animal behaviour and molecular biology and I used to read everything I could get my hands on, on both of these subjects. But I had a very different reaction to what I read. When I read in molecular biology, it was absolutely fascinating, and I’ve described it as a play being played on a stage in heaven. It was all wonderful, but I never felt jealous because, as an undergrad student in Bangalore, the thought never crossed my mind that I could have done those things. But whenever I read a paper in animal behaviour, in addition to feeling awe, I felt jealous. I felt why did I not do this? it’s something I could have done. That is the difference in my reaction to these two kinds of things. I couldn’t have discovered DNA polymerase as an undergraduate in Bangalore, but I could have discovered ‘imprinting’. So it certainly depends on what I can do and what I cannot do. If it’s something that anybody can do, and you do it, that’s great. If only you could do it, and you did it, then well it’s okay, but not that great.

HS: Can you give us some specific examples of work, like imprinting, that impressed you?

RG: There I have this whole set – I have written about it - of examples from both fields. Let me give you a recent example to emphasize that correctness is not important. When WDS Hamilton [1] came up with his idea of inclusive fitness, he realized, and only he realized, that because of haplo-diploidy, it’s easier for Hamilton’s rule to be satisfied in Hymenoptera than any other group of animals, because the relatedness between true sisters is 0.75. This was a major breakthrough because 11 out of 12 independent origins of eusociality had happened in the order Hymenoptera, which represents only 2% of the animal kingdom. In the remaining 98%, it happened once (in termites). In those days that’s all that was known: 9 or 10 times it happened in 2% of the animals and once in the remaining 98% and it is the former group that was predisposed to eusociality because sisters were related by 0.75. It turned out to be wrong in the end but that is completely irrelevant. To me, this was a creative leap. And I wished I had thought of it. Even today, even though I have been partly responsible for proving that it is wrong, I still feel I wish I had thought of it. The original formula of what we now call Hamilton’s rule was creative on its own but it was even more creative to realize that in haplo-diploidy it works much more easily. Or take Trivers’s [2] work. Just the whole idea of parent-offspring conflict is such an elegant, such a beautiful, idea. Anybody should have thought of it, especially after Hamilton’s paper in 1964. But nobody thought of it between 1964 and 1972. If you just look at the idea, it is so creative. That there would be a zone where both parent and offspring would agree that more investment should go to the offspring, and then there would be a period when they disagree, and finally there will be a period when both will agree that no more investment is appropriate. I wish I had thought of it. If I think hard I can also come up
Standing Conventional Wisdom on its Head

with experimental strategies or designs that I consider creative – Von Frisch’s [3] experiment, for example, where he came up with the so-called ‘fan experiment’. He wanted to prove that honeybees actually got information about the direction from the dance of the scout bees. So in his experiment, he trained bees to take sugar from a particular feeder at a particular angle say, 250 m from the hive. To test their knowledge, he put not one test feeder but an array of test feeders, and he didn’t put them at 250 metres but at 200 metres. Now, these two are strokes of the genius. He didn’t put them at 250 metres but nearer because he wanted to rule out the possibility that, at 250, the original bee had left some scent. And then by having the array rather than a single test feeder, he realised that, the bees would make an error indeed; but the error should be symmetrical on both sides, and they should fall off, and the maximum number should be in the middle, and then there should be a symmetrical fall off on both sides. That’s exactly what he found. Absolutely brilliant!

Or even the very simple primitive experiment that Tinbergen did to show that landmarks are being used by digger wasps to recognize their nests in the ground. Again, when something is quick and dirty it is even more charming. Tinbergen worked in this place where the wasps kept making holes in the ground and raised their brood there, and he saw that the holes all look the same but each wasp went only to its hole. How do they manage that? He said maybe the wasps have a detailed knowledge of the landmarks around their nest. Now how would you test this idea? Today we might take very detailed photographs and use pattern recognition software and say the grass here is a little shorter and there it is a little later. We can get the computer to map the exact landscape, etc. But Tinbergen didn’t do any of that. He reasoned that if they are using landmarks and the landmark differences are very subtle, he can exaggerate the differences. There were lots of dried pine cones lying around and so he put an array of pine cones around the nest and let the wasps fly in and out and learn it a little bit. Then he removed those pine cones and put them a little bit away and reasoned that if pine cones are what it has learnt it should go to, then it should go to the new place without the nest and not to the original nest now devoid of pine cones. And sure enough, that’s what the wasp did. Then he asked whether they see the pine cones or do they smell them? He now dipped the pine cones in alcohol to remove whatever smell they may have and put them back. Nevertheless, the wasps still went to where the pine cones were, suggesting that they are not using smell.

In another experiment von Frisch wanted to see if bees had colour vision, so he showed that they could distinguish between blue and green. But then one could distinguish blue and green because they may appear as two shades of grey. How do you remove that possibility? What did von Frish do – he goes to an art shop and asks for every shade of grey paper in stock. He gives all alternatives of grey and says that the bee must be confused by at least one of the shades of grey if it is learning to distinguish between two colours as shades of grey. The bees did not confuse the colours with any shade of grey. I would give that piece of work the prize and not for somebody who went into the brain and recorded everything and showed that they had the right neurons to have colour vision. All that is okay if you can afford it but what von Frisch did was the work of a genius.
HS: How do you encourage and increase creativity in your lab?

RG: One of the easy ways to do this, which we do all the time, is to discuss other people’s work. I promote this idea of appreciating something not because it is sophisticated, not because it’s published in Nature, not because it’s correct, but because it is very original and creative. So you can promote this philosophy by constantly judging other peoples’ work and then injecting this philosophy while making those judgements. The harder job is to actually get students to become creative themselves. If you are the supervisor, then on the rare occasion when two students come up with two different ideas you can say why you like one or the other based on these criteria. Although that doesn’t happen every day. In short, there is no better way than to lead by example – be creative yourself, but that, of course, is harder still!

References

I woke up on 11th December 2017 with the news that Lalji or Dr. Lalji Singh (famously known as the Father of DNA Fingerprinting in India) died of a massive heart attack on the previous evening (10th December). I was to chair a meeting on that day away from my workplace and it took a while to compose myself to carry on the work. Personally, I owe Dr. Lalji Singh a lot for my professional growth. Of the 12+ years I spent at CCMB, Dr. Lalji Singh was the Director for more than 9 years. Having worked with him so closely in those years, I thought I would express my thoughts after few days to avoid emotional outbursts.

Much has already been written about Dr. Lalji Singh in different newspapers and online platforms about his early work on sex-determination, identification of minor satellite DNA from sex chromosome of the snake (the Banded krait), and subsequent use of the same in DNA fingerprinting, etc. Much has also been written on how he improved the infrastructure of CCMB, mentored and supported young faculty (such as me at that time) and students. While writing this obituary, I thought of highlighting how Dr. Lalji Singh’s work and life is a fine example of bringing science to the public, and how this process is an important way of doing good science.

Scientists, more so those pursuing blue-sky research, often shy away from communicating with the general public. We mostly interact with anonymous peers, keep improving our science based on their comments. While communicating with those peers, we safely assume that they would not challenge us on known ‘dogmas’ and, therefore, we would describe only our experimental results in great detail and push the frontiers of knowledge by a few nanometers. Whenever we try to explain our work to the lay public, we need to give long introductions and their questions ‘out of ignorance’ on fundamentals are irritating and we tend to get derailed. We either give up, or only talk of some well-known facts in the pretext of ‘popularizing science’.
Dr. Lalji Singh’s work in the late eighties and early nineties indicated that he has identified DNA fragments that may help to fingerprint human individuals with as good accuracy as the probes used in UK and USA. While many molecular biologists, statisticians and social activists were sceptical and even opposed him, he still went on and made a public announcement that he has developed an ‘indigenous’ DNA fingerprinting technology, only the third country in the world to do so. Those are the days when the Press never reported anything about science in India. Nevertheless, it was reported and forgotten by the public quickly. The fact that Dr. Lalji Singh went public built much pressure on him to ensure that his work stands the scrutiny of the public. While scientists excuse us if we biologists say that our discovery holds good only under so and so conditions, the public does not accept such exceptions. Therefore, his lab worked like a factory to standardize the fingerprinting technology with innumerable blind and double-blind experiments. The best statisticians were consulted to ensure that the results be reported with an accuracy that is difficult to refute. Finally, what came out was a truly trustworthy technology, which now is a household knowledge.

Unlike medicine, any new knowledge or technology that challenges our social system attracts maximum opposition and even ridicule. Galileo went through this. Darwin went through this. Many more well-known and lesser-known people have endured humiliation and insult while propagating new ideas. Dr. Lalji Singh was no exception.

His new discovery didn’t go completely unnoticed by the public. A young lady (I am told, was educated only up to the school level) in Kerala read about his work and requested the Judge handling a paternity dispute that she was fighting in the court to seek DNA fingerprinting as an evidence. The Judge approached Dr. Lalji Singh, who readily agreed. He went to a small town in Kerala, a land and language equally alien to him. He took much pain explaining to the court what is DNA, what DNA fingerprinting is, etc. He also had to endure humiliation from the defense lawyer accusing him of a false claim that DNA fingerprinting is possible to verify the parental identity of a child. The court finally admitted his tests as evidence and gave the verdict in favor of the mother. Although this made both DNA fingerprinting and Dr. Lalji Singh famous, the technology was far away from general acceptance. The second case, was a dispute involving a ‘godman’ who was accused of raping the inmates of his ashram. Legendary lawyers were engaged to fight for the accused and Dr. Lalji Singh had to answer a volley of humiliating questions. I guess, most scientists would have given up in his place. But, Dr. Lalji Singh did not. He kept referring to the science of DNA and development of the technology of DNA fingerprinting and its precision; all along keeping his language civic against the language that the lawyers use as a matter of right. The verdict of this case made DNA fingerprinting a household name in India and its acceptance in all courts in India.

As mentioned above, general perception among scientists is that they only need to communicate within the peer group as the public, anyway, will not understand their work. As a corollary, only the scientists are capable of thinking of applications of a piece of knowledge that they know of and not others. When DNA fingerprinting became famous and solved some sensational cases such as Rajiv Gandhi’s murder, tandoor murder case, etc., a Government
officer in Commerce Ministry approached Dr. Lalji Singh asking if his technique can be used to fingerprint rice! He had a problem in hand. Basmati rice exports were badly affected due to adulteration, and importers from Europe and other countries were losing trust in Indian products; although the maximum demand was for ethnic Basmati from the foothills of Himalayas, particularly from the Tehri region of Uttarakhand.

A colleague of Dr. Lalji Singh, working in the Centre for DNA Fingerprinting and Diagnostics (CDFD), Late Dr. Nagaraju, readily accepted this challenge. Dr. Nagaraju, a Zoologist, was primarily working on silk moths. Even today most academic places fight for their identity as a botanist or a zoologist or a microbiologist. But, CDFD was not one amongst those. Dr. Nagaraju was encouraged to take up this task. He quickly developed a way and provided the DNA fingerprinting services to identify authentic ethnic Basmati thereby reducing adulterations that eventually improved exports and added to our exchequer. This is a fine example of a member of the public imagining a scientific solution to the problem in hand and a scientist making it a reality.

Dr. Lalji Singh, therefore, will forever be missed not only by his colleagues in scientific institutions but also by the people of India.
MEETING REPORT

Outcomes and Lessons From the First CDRI-NRDC-Industry Conclave

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Abstract

The first Industry Conclave organized jointly by the CSIR-CDRI and the National Research Development Corporation (NRDC) was held on 15–16 September 2017. This document summarizes the learnings from the formal panel discussions conducted during the meeting, as well as interactions among the delegates during the exhibition that showcased the CDRI product pipeline, services offered and proposals for collaborative R&D. It became evident during the course of the conclave that although there was broad consensus on the societal and intellectual value of pursuing ‘basic’ science, there is a significant ‘trust deficit’ between the Indian academia and the Industry. Research funding and its sources, and evaluation of research output continue to be contentious.

Keywords. Pharmaceutical Industry; Drug Discovery; Industry-Academia Interaction; Research Priorities; Funding; Science Policy.

Introduction

This document was initially written to serve as an aide-mémoire for CSIR-CDRI’s effort to engage more meaningfully with the pharmaceutical industry. Such engagement, of necessity,
requires that a broad range of issues and concerns be discussed freely, so that the interrelationship between CSIR-CDRI, other academic and research institutions and the pharmaceutical industry can be placed on firm footing. Acknowledging the obvious way in which CSIR-CDRI can interact with the industry, viz., providing readymade technologies, services, human resources and consultancy, an attempt is made to increase the ambit of this discussion by flagging issues that lie at the core of such interactions. This document is therefore offered as a starting point for further engagement between the academic and industrial research communities in the pharmaceutical and health sciences on the one hand; and the management/policy community relating to the pharmaceutical industry on the other. We hope that clinicians and public health policy professionals would also be drawn into the debate.

The major part of this document, therefore, is a summary of Panel Discussions. Despite differences in the stated themes of the three Panel Discussions, there was an understandable overlap in insights and arguments put forward by the panellists. This was anticipated, since the three broad themes are interlinked. For the purpose of this report, statements have been classified under the most relevant theme regardless of the panel in which they were advanced. Statements have been summarized without attribution, and in a rough order of chronology, without any attempt at prioritization. A ‘recommendatory’ tone is also deliberately avoided. Additional documentation relevant to some of the points made is provided in the form of notes and citations for the interested reader.

The Panels

Three panels were assembled and were constituted as follows

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<th>Basic Research is the Foundation for Innovation</th>
<th>Technology Transfer: Industry Expectations and Concerns</th>
<th>Funding and Costing for Collaborative Drug Discovery and Development</th>
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Basic Research is the Foundation for Innovation

None of the panellists had any major disagreement with the basic proposition. However, many underlying nuances emerged very effectively and are as follows.

**The concept of a linear, stepwise progression from ‘basic’ to ‘applied’ to ‘translational’ or ‘developmental’ research is flawed.** The mechanism of action of nitric oxide in its multifarious roles in Biology became known much after angina drugs like glyceryl trinitrate had long been in use (Marsh and Marsh 2000). The linkages between Streptococcal pharyngitis, rheumatic fever and rheumatic heart disease were revealed by studies on the variations in immune responses of different patients (Wahi et al., 1989). Statins were discovered in the quest for an inhibitor of microbial HMG CoA reductase for use as an anti-microbial agent (Endo, 1992). Endo explicitly states that the search was for an antimicrobial agent, referring to his own research initiated in 1971 in Japan. However, a more recent review (Tobert 2003) does not refer to this. These examples and the individual and collective experience of the panellists, reinforce the view of research as an end in itself. Outcomes that are useful in a societal or commercial sense arise as offshoots of a general growth in knowledge. Multi-directionality and turbulence
are essential for good research. Transformative inventions do not draw on a single linear pathway of mechanistic enquiry but rely on an entire gamut of knowledge.

**Recognizing ‘innovation’ is difficult.** The very first experiments conducted with the aim of generating visible images of objects by means of manipulating the magnetic field, or to explore nuclear magnetic resonance in more than one spatial dimension produced results that were not immediately striking (Lauterbur 1989). However, these led to the development of MRI, 2-D and 3-D NMR, etc. Path-breaking work is often recognised only in retrospect. In the short term, it should suffice if ‘good’ science can be distinguished from ‘bad’ science. Since ‘innovation’ is difficult to recognize early on, ‘discovery’ and ‘invention’ should be sought instead, although the distinction between discovery and invention is often artificial.

**Research is not amenable to being ‘directed.’** It is best if research objectives defined by policymakers and the industry are simply placed before the research community. It is very likely that many of these will be taken up. However, attempts to channelize or direct research efforts towards desired policy or commercial outcomes are most likely to be self-defeating. If funding for goal-directed research is easier to come by, research on truly challenging problems will suffer. Specific calls for grants of funds to research proposals addressing a defined problem invite applications from researchers who struggle to make their expertise and interest fit into the purview of the call.¹

**Science that investigates mechanistic probability/causality is not always necessary for technology.** Although technology is necessary for scientific investigation, the reverse is not always true. Thus, a technological outcome of scientific research may or may not necessarily come about, but technological progress certainly provides better tools to engage in research. A ‘base and superstructure’ model may therefore be inadequate to understand the interrelationship between ‘basic’ science and technological ‘innovation’.²

**The pursuit of science is empowering.** The primary societal benefit of scientific research is not limited to the generation of usable technology. Understanding cause and effect is crucial to the empowerment of marginalised people and is a primary purpose of scientific investigations. Not only do researchers themselves achieve empowerment, but research results that establish causality can re-claim the realm of explanation from exploitative socio-cultural power structures. Thus, science contributes to the aim of achieving social justice (Barton et al., 2003). Scientific investigations inform several elements of State policy and provide for evidence-based governance. Complementarity in science and technology research can lay down ground

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¹ The list of all 25 successful applicants for healthcare projects under the Nano Mission in 2017 is provided as an appendix. It includes organic chemists, electrochemists, biochemists, pharmacists, a mechanical and a textile engineer, a bioorganic chemist, a polymer chemist, a structural biologist, an enzymologist, a medical doctor, a zoologist and a physicist.

² The distinction between science and technology has been extensively debated. Whereas science addresses ‘what is’ and technology addresses ‘what should be’ (see: Skolimowski H. The structure of thinking in technology. Technol. Culture 1966; 7:371-83), the areas of interest of these two fields are apparently divergent. The distinction between technology and craft is based on the theoretical underpinning of technology as opposed to the skill/creativity required for craftsmanship. Two kinds of theories are postulated for technology—‘substantive theories’ or ‘knowledge that (e.g., x always happens)’ and ‘operative theories’ or ‘knowledge how (x) can be made to happen’—see: Bunge M. Technology as Applied Science. Technol. Culture 1966; 7:329-47; and: the Stanford Encyclopaedia of Philosophy. https://plato.stanford.edu/entries/knowledge-how/ (accessed 29 Nov 2017).
rules to prevent hasty implementation of inappropriate technological fixes (Sarewitz and Nelson 2008).

Technology Transfer: Industry Expectations and Concerns

The present scope and extent of technology transfer from academia to the pharmaceutical industry is limited. About 8–10% of technology development projects pursued in the academia are ultimately transferred to the pharmaceutical industry. CSIR does slightly better, transferring 18% of such projects to the industry. However, ‘green shoots’ of entrepreneurship are now visible, wherein academia is venturing into start-ups.

Collaborative developmental research is a viable option. The majority of Indian pharmaceutical companies have strengths in process chemistry and formulations, but not in biology. It would be fruitful if biology expertise available with the academia is more accessible to the industry, particularly for drug discovery research.

Not meeting timelines is Indian academia’s greatest shortcoming. The trajectory of global developments in each therapeutic area is different. For example, in oncology, if the time-to-market is greater than five years, the product under development becomes irrelevant. Similar timeframes are applicable to other areas. Decision-making protocols in the Indian, as well as global industry, are likely to terminate projects that do not meet timelines, regardless of innovative merit (Jekunen 2014). Further, financial costs of research expand to unviable levels if deadlines are not met, compromising returns on investment. Therefore, it is best if academia does all the ‘homework’ before approaching the industry for collaborative product development.

The mobility of personnel in companies is a significant hurdle in sustaining collaborations. Collaboration requires building rapport. Also, new incumbents tend to view their predecessor’s effort with greater scepticism. Institutional mechanisms are not in place within the industry to nurture long-term collaborations. Personnel mobility also adversely affects adherence to timelines.

The Indian academia is largely unfamiliar with the regulatory landscape. While it may be acknowledged that drug regulation tends to verge on the absurd, the Industry has no choice but to work within the regulatory framework. Thus, data generated in facilities that do not have accreditation by agencies recognized by the Drug Controller General of India [DCG(I)] is very often not appropriate for the purpose of seeking permissions for clinical trials or for product registration. If they are serious about technology transfer, academics must read and understand the regulations governing drugs, biologicals, devices, phytopharmaceuticals,
AYUSH products etc., as applicable. Data integrity and reproducibility of results must be ensured.

**Clinicians have to be engaged with in detail.** Clinicians are even less interfaced with industry than are academic researchers, and bridges must be built. Extensive consultation among several clinicians, academics and industry-based colleagues will not only strengthen the therapeutic rationale of a discovery product, it can also open up newer areas of research and product development.

*Public-funded drug discovery and development research on low-profit market segments should build links with pharmaceutical public sector units.* Large sections of the society and public health needs of the country require medicines that are not sufficiently profitable to sustain private sector companies. A win-win situation can be engineered, wherein PPSUs can derive benefits from cost reduction, import substitution, therapeutic value enhancement, etc., as the outcome of academic research. Affordability as a policy should be a priority for drug research.

*The industry-academia relationship is fraught with misunderstandings.* During the discussions, as well as on the sidelines, the misconceptions prevalent among academia and industry-based colleagues became apparent. Some of these are listed with the objective of flagging issues that need to be addressed for the ‘trust deficit’ to be overcome.

**Academic Researchers’ Misconceptions**

**About the Indian Pharmaceutical Industry**

1. *The industry has a lot of money to invest, so we should try to maximize upfront earnings from technology transfer.* This is not true. The industry is not monolithic. Start-ups, MSME and generics companies are certainly not flush with funds. Even bigger firms have meagre allocations and stringent accounting for research budgets.

2. *The industry will have no compunction in stealing my idea.* While it is prudent to secure IP, academics must weigh the consequences of patenting early and thereby foregoing the advantage of a longer period of exclusivity. Most often, the industry-based colleague will have no time (or inclination) to work on your idea, much less possess the resources (see above) to be able to take it to fruition. Confidential disclosure agreements are sufficient for the protection of data exclusivity.

3. *The industry has no appetite for taking risks, has no interest in the science behind my research, and is only interested in making profits. (see #1 above).* Making money is not a bad thing, or a questionable motivation for drug discovery and development. The industry will take only as much risk as its R&D budget can afford. The level of validation (of the scalability of the
manufacturing process, the quality of evidence of safety and efficacy, etc.) is the major
determinant of whether or not a risk is worth taking.

4. The industry does not have sufficient competence to implement/execute my idea. Most
companies have limited portfolios. If a company has a product that is even remotely similar to
your target product profile, no concern about competence is valid.

Industry-based Colleagues’ Misconceptions About the
Indian Academia

1. Academics are only interested in publishing papers and going abroad to international
conferences; they are ignorant about the industry and have contempt for it. If there are such
people, they’d better be left alone—and would have never approach the industry for
collaboration! An overture to the industry recorded from an academic is an expression of good
faith.

2. Academics don’t know how to convert an idea into a product. A considerable (and rising)
number of successful academic-entrepreneurs contradicts this view.

3. Academics are unwilling to align with the objectives of the industry. Academics are unwilling
to engage in work that offers no intellectual challenge.

4. Academics don’t know when to stop a research program. But they are perfectly willing to stop
a product development program if it appears infeasible. The pursuit of curiosity-driven
research need not bother the industry.

Funding and Costing for Collaborative Drug Discovery
and Development

The cost of drug discovery is difficult to estimate. US$ 250M is a figure accepted widely
among investors. However, different estimates vary 9-fold or more (Morgan et al., 2011). A figure
of $2.6B has been cited in the popular press in mid-2017. The cost of discovering and
developing Centchroman (ormeloxifene) entirely through public sector funding is not
recorded. Cost estimates of drug discovery in the Indian private sector follow the global trend
of factoring in costs of all failures during the relevant discovery/development life cycle.

[3] Although an estimate for the cost of developing α/β-arteether is available at https://thewire.in/author/amitra/ (accessed 26 September 2017); and is likely to be between 4.5-9 crores in real terms.
Outcomes and Lessons From the First CDRI-NRDC-Industry Conclave

The public-private-partnership (PPP) mode of collaboration has developed from a ‘loan’-based model in 1993 to grant-in-aid mechanism today, through the efforts of CSIR (DPRP, NMITLI, etc.) and DBT/BIRAC programmes. However, an optimal level or proportion of public funding for private enterprise is yet to be established.

Disbursement of public funds to the pharmaceutical industry has evolved over the years to the de-risk industry. The public-private-partnership (PPP) mode of collaboration has developed from a ‘loan’-based model in 1993 to grant-in-aid mechanism today, through the efforts of CSIR (DPRP, NMITLI, etc.) and DBT/BIRAC programmes. However, an optimal level or proportion of public funding for private enterprise is yet to be established.

Public and philanthropic funding for drug discovery and development is well-developed in Europe, USA, etc., but is not adequate to meet full costs. The Innovative Medicines Initiative has budgeted €3.3B for 2014–2024. This works on a PPP model. Calls are initiated when a consortium of EFPIA companies is formed. The Karolinska Institute is a major beneficiary. The external funding of the MIT in 2016 was $428.1M and the total expenditure on consumables was 3350M. Non-government funds typically contributed barely 28%. This is vis-à-vis a public-funded institution that has the strongest IP portfolio in the world.

The measurable output of public-funded drug research is meagre worldwide. Notwithstanding the Bayh-Dole Act (Markel 2013) in the USA, 153 new FDA-approved drugs, vaccines, or new indications for existing drugs were discovered between 1971–2011 through research carried out in public-funded institutions. These are 93 small-molecule drugs, 36 biologic agents, 15 vaccines, 8 in vivo diagnostic materials, and 1 OTC (Stevens et al. 2011). However, the US FDA’s Orange Book has very few entries where public-funded institutions such as MIT or Johns Hopkins are the applicants. In the 40-year period, USFDA granted a total of 1541 approvals, of which 143 (<10%) were applied for by institutions themselves. Since the USA does not have any mechanism of public-sector pharmaceutical manufacturing, their model is simply to create a vehicle for the transfer of IP generated by public funds to the private sector. In contrast, Brazil and many Latin American countries, Russia and Eastern European/Central Asian countries, India, China, Indonesia, Sri Lanka, Nepal, etc., have a ‘mixed economy,’ where pharmaceutical manufacturing has both private and public sector players. In Cuba, for instance, government produces drugs and vaccines that cover 80–90% of the market. Russia, wherein 100% of pharmaceutical production was once government-owned, has progressively diluted government shareholding after the collapse of the Soviet Union. However, Russia now recognizes that relinquishing government ownership of the means of production of medicines has strategically weakened the country, and its 2020 Policy Objectives aim at import substitution and self-reliance. China has a pharmaceutical manufacturing and pharmaceutical/biotechnology R&D sector that is >70% government-owned.

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[8] http://www.businesswire.com/news/home/20150924005659/en/Research-Markets-Cuba-Pharmaceutical-Market-Report-2015-2018. This is especially ironic for India, since the first ever pharmaceutical plant in Cuba was set up with help from Sarabhai Chemicals, an Indian private sector company. Cuba returned the favour by setting up Hindustan Antibiotics Ltd. Today, the Cuban QUIMEFA constituents source most of their discovery research fund from Cuban public-funded institutes. Heber Biotec SA have even transferred technology to, for instance, Panacea Biotech.
**Venture Capital (VC) and Angel Investor funds for drug discovery and development are difficult to come by.** VC firms are funding hospitals, pharmacy chains and e-pharmacy, not research. Short-termism is generally encountered, and VC gets frustrated if there is no exit after even 10–12 years of a drug discovery programme have elapsed. VC firms do not have an objective framework of conducting due diligence; they instead rely on personal knowledge and peer networks to assess drug research programmes to invest in. Prediction of returns on investment in India for drug discovery and development is not easy. Unpredictability is due to the IP regime and its enforcement, and the therapeutic trajectory of disease areas (e.g., warfarin was out of the market within 10–15 years). It is likely that VC firms will invest in high-technology/ high-cost areas such as biosimilars and RNA interference therapeutics, but small molecule drugs are not on the radar.

**The Indian pharmaceutical industry cannot be expected to fund drug discovery and development research.** Profit margins may be high, but budget allocations for meaningful R&D are meagre. A drug pricing regimen is in force in India. Exports are declining. The dominant business model is to provide a cheap manufacturing base for multinational pharmaceutical marketing firms. This results in the core competence of the pharmaceutical industry moving decisively to provide manufacturing services for technology that is ready to deploy, rather than investing in technology development.

**PPP model of funding deserves a second look and a bold step should be taken to deploy public funds for better outcomes.** Since 1993 to date, the industry has been reluctant in setting up plants for manufacturing active pharmaceutical ingredients (API), even if government funds and incentives are made available. More than 95% of start-ups in the pharmaceutical sector that were funded by government are inviable. India is now insecure in terms of manufacturing key starting materials, intermediates and API. This state of affairs must also be viewed in the context of India-China relations. The oldest VC firm in India continues to have the Technology Development Board as an investor (~30 crores). Therefore, a re-look is required before the policy of prioritising funding for PPP collaborations is continued to be carried forward.

**Policy objectives of drug affordability and access require investments in public-funded drug research.** Prices of medicines can be controlled, kept in check, and most often significantly reduced if there is a market competition without a violation of our WTO obligations regarding TRIPS. The second goal is to ensure access to essential medicines. In a drug prices control regime, where the National Pharmaceutical Pricing Authority (NPPA) caps the prices of drugs on the National List of Essential Medicines (NLEM), it becomes necessary to offer the private sector blandishments such as subsidies, tax breaks, duty exemption, utilities, services, assured or captive markets — in short, all the negatives that are associated with public sector manufacturers; just to ensure that supplies are available. The WHO summarized arguments for and against public-sector manufacturing of pharmaceuticals by 1997 (Bennett et al., 1997). In retrospect, their analysis and projections were not borne out of events. WHO had not considered pharmaco-economics models of lot-discretization as a means of reducing cost and insisted that economies of scale are the sole means of doing so. The rise
of IT-enabled demand aggregation and inventory control mechanisms were not considered. Lastly, they did not factor in the role of incorporating public-sector research outputs into public sector production.

**The notion of a self-sufficient public sector is erroneous.** The Indian pharmaceutical industry has progressively reduced its investment in new drug discovery because the return on investment is not sufficient despite high profit margins. Suppose a public-funded institution like CSIR-CDRI licenses a drug that has an annual sales of ~100 million USD (equivalent to INR 6500000000) it typically gets 2% (INR 13 crores) as royalty. To earn its annual budget entirely from royalty, 10 blockbusters drugs must be launched every year from CSIR-CDRI—something that no entity in the world is capable of achieving. Public institutions should address issues that are societally useful and are not addressed by the private sector. India is now API-insecure, and this must be viewed in the context of India-China relations. India has ignored public sector manufacturing of APIs to its own strategic peril. This has been realised, and it is now rumoured that Niti Ayog has recommended setting up Mega Pharma Parks with an outlay of 5000 crores of public money, on the lines of SEZ. It is incomprehensible why greenfielding an SEZ is a better option compared to investing a tenth of the capital on existing Pharma PSUs. Thus, to argue that public sector drug research and drug manufacturing should be self-sustaining even as it addresses the needs of affordability, access and novelty — while private enterprise should receive subsidy — is perverse.

During peer review of this manuscript, it was suggested, among other things, that we should “flag disagreements and the bases thereof that arose during the conclave regarding the general propositions” to “make the subsequent conversations more substantive.” As pointed out in the Introduction, we have reported general propositions without attribution to a specific panellist, or the discussants on the floor of the house, or in the sidelines. This was a conscious decision, as we believe that anonymity is conducive to wider dissemination of views. We, therefore, submit that attempts on our part to identify disagreement (rather than consensus), while certainly helping to focus on the debate between two clearly identifiable entities, do not serve our purpose. We instead hope that this reportage has successfully highlighted the shades of informed opinion spread across a spectrum of diversity — regardless of the formal affiliation of an individual: to the pharmaceutical industry, the academia, the administrative or the funding bodies. And that, indeed is an extremely encouraging sign that this debate will be productive.

**Acknowledgments**

This is CSIR-CDRI Communication Number 9605.
## Appendix 1

List of successful nanomission projects funded by DST in 2017

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<th>Sr. No.</th>
<th>Date of Sanction</th>
<th>DST Reference Number and Project Title</th>
<th>Principal Investigator details</th>
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<tr>
<td>1</td>
<td>03.05.2016</td>
<td>SR/NM/NS-1252/2013 Regulatory pathways and role of zinc oxide(ZnO) nanoparticles in angiogenesis</td>
<td>Chemist Department of Biomaterials Indian Institute of Chemical Technology Hyderabad 500 007</td>
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<td>2</td>
<td>23.05.2016</td>
<td>SR/NM/NS-1376/2014 Carbon Nanotubes Based Electrochemical Immunosensor for small Cell Lung Cancer Diagnosis</td>
<td>Electrochemist (studied at Ruhr Universität Bochum) Indian Institute of Technology Ropar 140 001(Punjab)</td>
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<td>3</td>
<td>30.05.2016</td>
<td>SR/NM/NS-01/2015 Fabrication and characterization of hybrid nano sponge dressing for healing of infections burn wound</td>
<td>Biochemist Department of Biotechnology Mepco Schleck Engineering College Sivakasi 626 005(Tamil Nadu)</td>
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<td>4</td>
<td>05.07.2016</td>
<td>SR/NM/NS-1118/2014 Brain targeting of an anti-epileptic drug via intra-nasal nanostructured lipid carriers</td>
<td>Pharmacist Department of Pharmaceutics Amrita School of Pharmacy Health Science Campus, AIMS Ponekkara, Kochi 682041 (Kerala)</td>
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<td>5</td>
<td>13.07.2016</td>
<td>SR/NM/NS-1141/2015 Multifunctional Magnetic Nanoparticles for Cancer Theranostic Applications</td>
<td>Engineer Department of Mechanical Engineering Shiv Nadar University Noida 201 314 (Uttar Pradesh)</td>
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<td>6</td>
<td>13.07.2016</td>
<td>SR/NM/NS-1118/2015 Engineering of Self-assembled lapidated nanoparticles for cancer combination therapy</td>
<td>Bioorganic Chemist Regional Centre for Biotechnology 3rd Milestone Faridabad-Gurgaon Expressway, Village Bhankri Faridabad 121 001(Haryana)</td>
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<td>7</td>
<td>20.07.2016</td>
<td>SR/NM/NS-1004/2015</td>
<td>Hybrid Magnetic Nanoparticle Aptamer Bio-sensor for On-Farm Early Pregnancy Diagnosis in Cattle</td>
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<td>8</td>
<td>03.08.2016</td>
<td>SR/NM/NS-1111/2015</td>
<td>Evaluating therapeutic potential of polyglutamine aggregation peptide inhibitors through nanoparticles-based-delivery approach in Huntington’s disease</td>
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<td>09.08.2016</td>
<td>SR/NM/NS-1470/2014</td>
<td>Synthesis and characterization of siRNA loaded ligand bearing PLGA nanoparticles for targeted delivery to the lung cancer</td>
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<td>06.09.2016</td>
<td>SR/NM/NS-1091/2015</td>
<td>Development of biodegradable nanoparticles for concomitant delivery of anti-cancer peptide/DNA and chemotherapeutic drugs for cancer therapy</td>
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<td>11</td>
<td>15.09.2016</td>
<td>SR/NM/NS-1135/2015</td>
<td>Development of nanofibrous membrane for wound healing by controlled release of Indian honey and curcumin</td>
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<td>Delivery of miRNA-nanoparticle complex to promote repair and regeneration after myocardial injury</td>
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<td>Molecular structure and supramolecular packing of misfolded proteins within the amyloid nanostructures: A Nanoscale Biophysics Approach</td>
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<td>Low cost diagnostic system for public health surveillance targets bacterial enteric pathogens</td>
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<td>16</td>
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<td>Hepatocyte Targeted Carbohydrate Anchored Smart Nanostuctured Lipid Carries for treatment of Malaria</td>
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<td>Evaluation of the potential of siRNA loaded lactoferrin nanoparticles for the treatment of prostate and testicular cancer</td>
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<td>18</td>
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<td>A Therapeutic approach of targeted delivery of miRNAs through nanoparticles to control metastasis of Triple Negative Breast cancer in-vitro and in-vivo</td>
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Bennett, S., J. D. Quick, et al. (1997). Public-Private Roles in the Pharmaceutical Sector:
Implications for equitable access and rational drug use. Geneva, World Health Organization.


This is an interesting book dealing with the Sociology of Science. The origin of experimental science in the modern sense can be traced to the 15th century Renaissance period. Of course, scientific inquiry was being conducted in many civilizations much before the European Renaissance. Through colonial rule, this post-Renaissance European science, also called western science or Modern science, spread to the rest of the world. Though sometimes defined in the pure sense as a deductive logic-driven (hypothesis driven) activity, science in practice, however, employed many other additional approaches including inductive reasoning, reflective thinking and others. This curiosity-driven activity was named Natural Science to distinguish it from Natural Philosophy. Natural Science is akin to Philosophy as both seek the TRUTH.

Science deals with natural phenomena. It seeks patterns and mechanisms (cause and effect) underlying natural phenomena including living processes or biological phenomena. In the last 500 years, science and technology have grown enormously and attained central importance in dictating and driving national development in many countries. Many thinkers have analyzed this activity called Natural Science and have commented on it. Rationality-driven science has also come into conflict with socio-economic-cultural characteristics of societies, which practice and apply science and technology in solving societal problems and to fulfil national aspirations. Many sociologists have reflected on the mutual interaction between science and society (read educated layman).

The art of doing science has become a technology by itself. This is more relevant in the field of Biology. Ethical problems also crept in when science became an enterprise, especially in the developing countries. Douglas Allchin reminds us that even in the advanced countries which gave us science, ethical problems have arisen. Public perception of science and scientists also got increasingly romantic or hostile depending on perceptions. In many cases, scientists themselves were to blame for hostile reactions from the society. Scientific breakthroughs were being presented as stories of heroes and results of extraordinary intuitions. Certain scientists and pharmaceutical manufacturing industries made unjustifiable and false claims as well.
This book discusses over twenty-five scientific research reports, all of which have had a large impact on research and education in the field of Biology. Some of them were perceptions transmitted through oral (teaching) or written (reviews of fields and ideas) routes. Some were conceptual breakthroughs and brought about a ‘paradigm shift’ in our understanding of those areas of Biology. The author has taken great pains to obtain anecdotal details about each of these major developments in Biology and related areas. Two aspects of these discoveries/developments have been analyzed in detail by the author. First, in terms of assigning academic credit, Allchin has shown that someone who got recognition and awards and were in limelight did not deserve more than some others who may or may not have gotten their due recognition. The author carefully distinguishes ‘recognition by peers’ and ‘recognition by award committees.’ Second, in some cases, the author tries to prove that society (peers) misunderstood and misrepresented a particular research work. The fallout has been misleading to the public as well as experts in the area. He particularly cites Darwin’s work and how some peers misinterpreted some of it to promote their own ideas, thus creating a social dilemma and ‘mental unrest’ in the public.

This book discusses, through case studies, one such abnormal behavior among some scientists and teachers of science. This refers to ‘sustaining certain misplaced assumptions’ leading to what almost amounts to ‘myth construction’ among elite scientists as well as among non-experts. This book of 28 and odd chapters is divided into 7 sections, each of which conveys a ‘misconception of science’ in popular mind (read educated layman including teachers of the domain knowledge). The book is a set of essays written with great care about many ‘misconceptions’ in Biology which are propagated, as the author says, through teaching, even by great teachers. It is an easy read. There is nothing to contest as all the case studies are true. However, the mindful reader should know that ‘good and critical-minded teachers’ do not carry these misconceptions/misunderstandings’ in their minds. The critical minds are constantly on the vigil to correct their lecture notes in the light of new developments or new research findings as well as historical aspects of a research work in a particular domain. A good teacher does not simply exchange second-hand information. He/she also studies the domain from many perspectives i.e. how factual is the information/idea, or how to avoid making value judgments, finding out any differences in the textbook from the actual content in the original paper(s), etc. In summary, a good teacher distinguishes, after investigation, content from the intent and does not exaggerate the importance of a finding and does not convey misconceived ‘facts.’

There are some chapters that do not seem to fit into the theme of this book. One such is chapter 3. This is about the famous cell biologist Alex Novikoff. The author has convincingly demonstrated that Novikoff’s work, including the discovery of Lysosomes and GERL, was influenced by his belief in Marxism or dialectical materialism i.e. the synthesis of opposites (in this case Organicism and Reductionism, the two mutually exclusive perspectives of what is Biology) to understand biological functions/processes. Academic institutions have to be insulated from political interference is a generally accepted idea. It is applicable to any creative activity. That does not imply that academic people should or should not be associated with political parties. I can think of another brilliant scientist, J D Bernal who was a staunch believer in Marxism and whose monumental work ‘Science in History’ has influenced many
people including scientists. Bernal’s celebrated student Dorothy Hodgkin went on to receive the Nobel Prize for her work on X-ray crystal structure of biomacromolecules. Both Novikoff and Bernal paid a heavy price for their beliefs. But what does all this mean? Is the sacred bovine the misconception that scientists should keep a distance from politicians or political philosophies?

The famous Meselson and Stahl experiment in Molecular Biology is discussed in chapter 4. The author asserts that many messy experiments preceded the final elegant experiment that is part of textbooks. As is presented in textbooks, this breakthrough work which provided elegant proof for the semiconservative mode of DNA replication in the area of Molecular Biology is a typical hypothesis-driven experimental design and execution whose results were consistent with the hypothesis. The author is unhappy that books do not tell us about the mess and confusion that exists in the minds of the scientists preceding the final results of an experiment. The author gives anecdotal historical details of how the final experiment was not conducted in one go and nor was it designed and conducted in a day’s work. Two scientists met by chance. One had a technique and the other had a problem. Wrong ideas were given by some mentors. Through mental agony, failed explorations and chaotic results, clarity eventually emerged on the choice of technique, and the correct answer, elegant and self-consistent, came out. The sacred bovine that is alluded to is the habitual presentation of scientific breakthroughs as simple, easily conceived and successfully executed clean experiments. We know that this is far from the truth. The author asserts the same idea. The sacred bovine is the habit to present science as a series of inspired work by superhumans endowed with extraordinary insights.

In chapter 5, the author attempts to show that the canonical deductive logic is not the only way science is done. Nobody, of course, denies this. Inductive reasoning, reading, consultation, collaborative experimentation, discussions, etc., are all part of doing good science. The author attempts to show that the pursuit of science, in reality, is far from being idealistic and patterned work. There is nothing new in this revelation. It is not very clear what is the sacred bovine in this context.

In chapter 6, the author refers to a well-known sacred bovine i.e. ‘Social Darwinism.’ Herbert Spencer coined the phrase ‘survival of the fittest.’ Darwin did not use this phrase. Observing that the fittest people only survive in a modern human society in a struggle for existence and that invariably such successful people are deficient in morals and values in life, people tried to generate support for various supremacist ideologies in Darwinian ideas on the evolution of organisms. Obviously, this is a very naive understanding of Darwin and his idea of evolution. To misunderstand the implications of Darwinism and then to blame Darwin for ‘perpetuating falsehood’ is, to say the least, not being fair to the great man. The author refers to a number of social thinkers who misinterpreted Darwin’s sayings and applied them to human behavior and socio-political prescriptions. Darwin has written volumes on the inevitable evolution of morality in all eusocial groups. It is a consequence of living in groups (society), i.e. social organization of living. One can observe the same phenomenon in eusocial insects and other animal groups. Social instincts automatically become transformed into moral principles. Darwin wrote about four conditions for the evolution of morality. Individuals may be selfish but social good overcomes this. It is a learnt behavior that can eventually appear like instinct.
Darwin always advocated compassion towards the weak. He had ten children whom he treated equally. The author has done great service in bringing out the fallacy in drawing wrong conclusions from the idea of 'Selfish Gene.' Social Darwinism is not Darwin's idea. Malthusian ideas on competition for resources led to appropriating Darwinian ideas of evolution by Natural Selection and applying to human behavior. The author has done well in denouncing this aberration and mischievous interpretation labelled Social Darwinism – “another sacred bovine” in the words of the author. In fact, the author has coined a new phrase ‘Amplification of the Adapted’ instead of the ‘survival of the fittest.’

Another sacred bovine that the author deals with is through the discussion of the work of Joseph Priestley, Ingenhousze and others in the context of the discovery of Photosynthesis. Priestley observed that plants restore good air by removing the bad air caused by putrefying dead mice in a closed jar. Plants can make a candle burn for a longer time in such model systems. Many people including Priestley could not reproduce these results later but had received the Copley medal from the Royal Society by that time. Later, Priestly made another mistake by claiming that sunlight alone can do the same job; plants are not necessary. It was Ingenhousze who corrected all the details and showed that plants in the presence of sunlight can restore good air. It led to the discovery of photosynthesis. The author calls Priestley’s work as a comedy of errors. He names many more like Linus Pauling, Francis Crick, James Watson, Paul Boyer, Peter Mitchell, Szent-Gyorgyi, Paul Ehrlich and Ilya Mechnikov, who were celebrated scientists but had made wrong claims for which they were not censured. The author says that sacred bovines like these (i.e. the mistakes they committed wasting huge amounts of public taxpayers’ money) are never told in the books. They are hidden from the public knowledge. Thereby a myth is created that these scientists are infallible. Let us remember that all these great scientists deserved their honours. Their overall contributions make the few mistakes they made and admitted to, insignificant. It does not lessen their greatness. What the author wishes to say is that Nobel Laureates also make mistakes. Of course, all of us know this. Many more examples of such mistakes can be brought out (Arthur Kornberg, Severo Ochoa, Theodore Winnick, Christian Anfinson, etc.). Further, many Nobel Prize-winning works have been shown to be wrong by other scientists in later days. The fact that science is self-correcting is of utmost importance. Others correct errors or clarify misunderstandings. It becomes a sacred bovine if we continue to honour certain scientists for the mistakes they did! No good teacher or scientist would only blame them for the errors and not respect them for their contributions!

There are many chapters in the book that deal with some aspects of science in practice but these do not deal with the central theme of this book and hence are not commented upon. These chapters, in fact, deal with unethical practices in science. That deserves a separate book! But these tragic stories have to be told. Ignaz Semmelweis introduced the practice of hand washing for all doctors handling childbirths. He had observed that most of them directly came from theatres where cadaver dissections were being conducted. Though the idea of infection or germs was not there, Semmelweis, for hygienic reasons, advised handwash procedures. The number of child deaths during or after birth drastically came down. Yet his colleagues harassed him, insulted him, and made him leave the hospital where he was employed. The author has hinted at racism having a role in this sad episode. This is not an example of sacred
bovines but an ethical problem. The author has also written about pseudoscience practices by many quacks who advertise about miracle cures!

A particularly disturbing sacred bovine is hiding the contradicting data from scrutiny by peers or even laymen. In the area of Evolutionary Biology, a famous research work taught as an illustrative example for Natural Selection is the story of peppered moth from England. The story has been told in black and white in the book. Before the Industrial Revolution, peppered moth was dominantly visible, while after the Industrial Revolution, it was melanic moths. The story in this chapter explained that predation by birds was the selection force. If one were to examine all the publications and all data, one does not get the popular version (what is in the textbook) of this story! In another equally, if not more significant case, Mendel’s work on pea plants, and subsequent work by others had shown no such clear dominance inheritance pattern or numbers especially in the case of round vs. wrinkled seeds. Mendel had studied more than 20 phenotypic characteristics. He had actually rejected many that did not segregate clean in the F2 generation nor gave clean ratios like 1:2:1. But the textbooks do not write about all this. In fact, Bateson, Correns or Tchermak could not reproduce Mendel’s patterns. How did Mendel become the icon and hero and father of Genetics, asks the author! Why is then the ideal story being repeated in textbooks? This is the real sacred bovine that scientists have to answer!

Many other misconceptions have been discussed by Allchin in this book. An interesting case is about William Harvey who is credited with the discovery of blood circulation. Malpighi actually saw capillary network joining arteries and veins. Literature quotes him as saying that he only confirmed Harvey’s prediction but Harvey neither could see capillaries with naked eyes nor predict their existence. He wrote about closed circulation without discussing where arteries end and how veins get blood into them!

Allchin writes about another sacred bovine in chapter 21. This time it is about the misplaced credit to Alexander Fleming for the discovery and use of Penicillin - the wonder drug. During that period, many scientists were looking for antibiotics. Chances of a penicillium mold spore landing on the bacterial lawn plate in Fleming’s lab from the air was zero as the author recounts. It must have come from a neighbouring lab. Many others made similar observations. Fleming had actually thrown that historically important culture plate into the sink for washing in detergent! Fleming never believed that penicillin can be produced in enough quantities to take to human trials. But for Ernst Chain and Howard Florey, penicillin would never be known as a wonder drug. It is their confidence and conviction that made them produce large quantities of the antibiotic for clinical trials. Fleming never attempted. The author hence, for justified reasons, believes that a myth was built around the whole work and Alexander Fleming was presented as a hero with extraordinary intuition. The author calls it a ‘myth-conception.’ A myth-conception, the author says, “constitutes an effort to naturalize an imagined ideal into the history of science.” I must add that for large-scale production of Penicillin and saving thousands of American soldiers in World War II, another scientist deserves equal credit if not more, and that is Dr. Yellapragada Subbarow, the greatest medical researcher of all times and who deserved not one but six Nobel prizes. He did not get any!
In summary, Douglas Allchin brings two sacred bovines to our notice. One, that there is a lot of misrepresentation in textbooks and classrooms about scientists or scientific breakthroughs. Some are outright myths that continue to be. We should ponder on the ways in which these stories sustain and a large section of scientists/teachers is not aware of the facts. And two, a large number of cases where undeserving scientists have gotten credit/recognition while the real heroes have died unsung and unrecognized. While we know that science, as a philosophy, has built-in safeguards against falsehood. It is a self-correcting system. It is like a living organism that is self-regulating, self-referring and self-replicating energy system. Reproducibility of results/observations eliminates all falsehood. Lysenko cannot last long. There is a lot to be done to improve the running of the scientific enterprise, especially in the third world countries. Much of the problem can be solved if we nurture a healthy peer review system. It should be made both competent and honest. In every branch of science, especially in Biology, interpretation has changed over the years, but the data remains the same. Many scientists who said something and were recognized have either themselves revised their stand or have been proven wrong by others. Hence, any expert or a good teacher corrects his/her understanding. However, public (educated layman) memory is rooted in the past. That does not get updated or revised. To blame the original scientist for this is being unfair. Science is self-correcting, undoubtedly. The author has misunderstood this as a self-made correction. Big scientists do not give up their pet ideas. But the system corrects the faults in the due course of time. For instance, Koch’s idea of cholera toxin being an endotoxin remained for 75 years until S N Dey disproved it.

This book is highly readable and very educative. In the words of Karl Popper, a non-falsifiable knowledge is not science. There are built-in checks and balances. To quote Thomas Kuhn, “Science progresses by paradigm shift.” Sometimes new data come which demand new interpretation of old data. History of science is very interesting to read but very difficult to write upon. Let us also remember that history is a social construct. Facts, however, do not change. No honest scientist intentionally misleads others. I recommend this book to the students of advanced science and those who are interested in the History, Philosophy and Sociology of Science.

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BOOK REVIEW

Breaking the Silo: Integrated Science Education in India

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*Breaking the Silo* is a novel and engaging look at three very pertinent themes in the present time: (i) the persisting divide between Science and Humanities disciplines in Indian institutions of higher education, (ii) the existing contexts and future possibilities for integrating what appears to be ‘two cultures’ and (iii) bridging the perceived gap between the natural and human sciences. These themes have been addressed in this book via reflective reports on pedagogic strategies in integrating Science and Humanities education that was operationalized by the CSCS (Centre for the Study of Culture and Society) in the period between 2006–14. The book is part of the series, ‘Culture and Democracy at the Millennial Turn’, which broadly seeks to engage with the ‘spirit of the times’ or millennial development goals that animated topical debates in the field of education and research. The significant goals and debates addressed in the context of this series title include the viability of experiments in fostering independent, privately funded spaces that could break free of the ‘disciplinary silos’ of orthodox institutions and engage with a range of academic practices unencumbered by ‘institutionality’. Breaking the Silo engages with the little-discussed topic of integrated science education (hereafter ISE) in India in our times and is, therefore, a significant contribution to scholarship on pedagogic practices in science and the humanities.
Organisation and contents

Breaking the Silo organises its contents through an emphasis on its broad thematic concerns as outlined at the start of this review. The Introduction and Section One titled ‘What it was all About’ offers an introduction to Higher Education Innovation and Research Application (HEIRA), the higher education programme of the CSCS, Bengaluru, that set out in 2008 to tackle the problem of disciplinary silos in knowledge domains of Science and Humanities. This was done through a series of institutional collaborations, namely with the Indian Institute of Science, Bengaluru, the Indian Institute of Science Education and Research, Pune and the Central University of Jharkhand. This section outlines the scope and aim of, what came to be known as, the ‘Integrated Science Education Initiative.’ This initiative reflected and deliberated upon the pedagogic inputs for the students of natural science, engineering and technology.

What is very interesting for the reader in this section is a history of ‘Science and Society’ initiatives in post-Independence India in a chapter by Dhruv Raina et al. Incorporating personal accounts of teachers and administrators, this section throws light on various obstacles and successes in the path of integrating the disciplinary concerns of the natural and human sciences. This section focuses on questions exploring ways in which various kinds of ‘integration’ efforts have succeeded or failed vis-à-vis science education in India. The questions ranged from an analysis of the fate of Philosophy and History of Science courses in various public and state institutions in the country to what made HEIRA’s integration efforts different from the ongoing attempts in institutions like the IITs. Section Two titled ‘Beyond the Metropolis’ and Section Three titled ‘Ways of Knowing, Seeing and Doing’ form the bulk of the book and are an exciting contribution to research and thinking in higher education in India. These two sections comprise chapters by instructors who were part of the Integrated Science Education Initiative and each one focuses on the ways in which their individual ‘integration’ attempt at CUJ and IISc were ideated, executed and received. Instructors who formed a part of the initiative come from disciplinary backgrounds as diverse as Physics, Sociology, Literature, Film Studies, Biology and Psychology among others. Their individual chapters in the volume offer not only a reflection on how they built and transacted their own courses but most significantly, the ways in which their involvement in an ‘integrated’ pedagogic experiment at premier science institutes in the country compelled a rethinking of their own disciplinary locations.
Integrated Science Education

This book will be of interest to educators from all disciplines in the Human and Natural Sciences as the bulk of its content comprises detailed and reflective course descriptions that suggest important directions in which curricular and programme design can go in undergraduate teaching. The reflections on a history of ‘integration’ experiments in India in *Breaking the Silo* are also especially useful in the context of the burgeoning number of private actors in the field of education in India. Private universities today function with fewer bureaucratic hurdles in their operations and can revisit and interrogate disciplinary silos in ways that public institutions may find more difficult. This book offers several important points of departure for newer, private educational initiatives that are already engaged in the process of reimagining Science and Humanities’ education in India.

However, a discussion of a standardised model of evaluating the courses taught across different sites and operationalizing a conceptual ‘integration’ across different disciplines would have improved the reader’s overall impressions of this experiment. For instance, course reflections in the section titled ‘Beyond the Metropolis’ read like concept notes for approaching specific interdisciplinary topics and do not engage very deeply with assessment strategies or modes of evaluating how students themselves (especially those in a non-metropolitan context, encountering disciplinarily alien content) approached the courses. While this could have been more a function of greater or diminished flexibility afforded by the institutional structures of the different sites where these initiatives were launched, the book could have featured a more standardised model of organising instructors’ responses to the teaching of their individual courses. Another gap is the book’s silence on how certain challenges that appear to recur in the ‘integrated’ classroom can be approached by any such future attempts. These challenges include, for instance, the perception among students at premier science institutes that courses in the Humanities are an insignificant and unnecessary part of their curriculum, and students’ low competence in English in particular and language in general, especially in non-metropolitan contexts. With an ever-greater number of students joining higher education from backgrounds of great socio-economic disadvantage, any educational initiative that aims to introduce Humanities’ subjects should be able to anticipate and address the issue of language competence.
*Breaking the Silo* leaves the reader with an informed understanding of why integrated science education is essential, but doesn’t explicitly isolate a set of reasons for why it hasn’t been very successful in India. It does, however, convey an overall impression about why ISE has remained ‘experimental’ and has failed to become an institutional fixture in higher academic institutions. For this reader, the obstacles to ISE in India that seemed most pertinent and in need of redressal were: a) the lack of teacher-capacity in interdisciplinary areas like History and Philosophy of Science, b) institutional apathy and disregard for knowledge domains outside their own ‘silos’, and c) curricula that are unable to equip students with the capacity to identify and solve ‘problems’. Philosophy of science courses or ISE themed courses that have a very short lifespan in institutions which largely foster courses in disciplinary silos cripple the possibilities of creating future teachers/researchers in interdisciplinary areas. Even when courses in the Natural and Human Sciences equip students to identify ‘problems’ in their chosen areas of study, these remain firmly rooted in a discipline and are often divorced from the multiple everyday contexts in which they operate.

Some omissions notwithstanding, *Breaking the Silo* signals at the importance of integrating the Human and Natural Sciences as a way of interrogating and enriching both disciplines rather than one mounting a critique on the other. Integration experiments like HEIRA illustrate the importance of fostering curricular spaces that facilitate questioning of the methods, objects of study and everyday practices of any knowledge domain.

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Mapping Patents and Research Publications of Higher Education Institutes and National R&D Laboratories of India

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This study will be of help to the academia and national R&D organizations to understand how major academic and R&D organizations of eminence in India have contributed towards the progress in various research and intellectual property rights (IPR) activities around the country.

Comments

The book is divided into eight chapters and one annexure. Of the eight chapters, last two chapters are dedicated to the progress in research publications and patents granted to higher education institutes and national R&D laboratories; and strengthening the patent ecosystem. The book is not intended to be a research thesis, but is designed to be a guide about the achievements of Indian higher education and research, and what needs to be done to improve further.
Chapter I on IPR regime narrates the 'history of IPR regime in India' based on the statistics of Indian Patent Office up to 2016. This chapter, divided into different sections, gives a brief narrative about the fields of invention, number of patents filed and granted, and the areas in which they are granted with a brief overview of patents filed by Indian and foreign companies in various disciplines. Section (1.1) on Patent Facilitating Centre of TIFAC is well written. TIFAC was set up in 1988 by the Department of Science & Technology (DST) with the objective to foresee technology information in select areas of national importance. It also conducts training and awareness programs, including programs exclusively for women. TIFAC has a database of inventions in the form of Eskawa A, B, C which is available on a website free of cost. Section (1.2) deals with the role of National Research and Development Corporation (NRDC) on 'IP protection and Commercialization.' NRDC has a repository of 2500 technologies, many of which have been licensed to various start-ups in different parts of the country. They also conduct a few awareness workshops and have a portal for the databank. Section (1.3) details another 'technology support system' set up by the World Intellectual Property Organization (WIPO) in India. This organization lays special emphasis on awareness, effective enforcement and IP commercialization. A cell for IP Promotion and Management (CIPAM) under the Department of Industrial Policy & Promotion (DIPP), Ministry of Commerce & Industry (GoI) has been set up as a professional body for the implementation of the National IPR Policy 2016. It also deals with special efforts by the Panjab University to rope in WIPO for guidance in several areas. Section (1.4) on CIPAM-A, Cell for Promotion of IPR in the Department of Industrial Property Management (DIPP), Ministry of Commerce, GoI, primarily deals with the awareness and implementation of patent practices as per the international laws, with centres set up in Punjab, Chennai and Vishakhapatnam. Section (1.4) deals with a very well-written 'Overview of Utility of Models.' Utility models have low novelty and non-obviousness, with a short-term right of 6–10 years in several countries. However, in spite of the incremental advantages of the utility models, they are not considered by Indian regulators. The authors have provided a good overview of the use of utility models in several European countries. I think there should be some protection under Indian law to utility models.

Chapter II deals with the 'National IPR Policy 2016' (dipp.nic.in/policies-rule). It lays the future roadmap for IPRs in India. Indian government recognizes the potential of innovative energy by Indians for a better future of India. It is a vision document that creates interlinkages, and synergizes between all sorts of IP, concerned statutes and agencies. It has a vision and a mission statement, with seven objectives beginning with the generation of IPs to Human Capital Development, and guidance to implement the National IP policy.

Chapter III WIPO was created in 1967 by the United Nations in Geneva for the promotion of uniform IP and practices throughout the world so that effective and uniform trade could be conducted on IP related products. It also conducts an economic analysis of how the government IP and innovative policies affect the economy of nations. WIPO administers this activity through 26 international treaties, which have been briefly described by the authors. The authors have also included a comparative table on the Summary of International Filing and WIPO’s Databases. The Global Information Network WIPOnet is very useful to this effect.
Chapter IV This chapter shows ‘Indian Web Portals’ related to patents and technologies. The authors have collated a comparative account of 14 different web portals of use to Indian innovators. Each web portal has its utility or limitations, because inventors do not like to disclose all details till the patent is granted, or till the technology is licensed. In this way, many a time the patents impede research activity.

Chapter V is on a composite analysis on research publications and patenting profiles of Indian higher education institutes and national R&D organizations (public and private; totalling to 904 organizations). The chapter has been worked out well. The methodology used for such a study, as mentioned on Page 63 of this document, is well worked out in the following manner:-

Publications (i) Retrieving the list of R&D laboratories from the official websites of respective ministries of GoI and the Directory for R&D Institutes, published by National Science and Technology Management Information System (NSTMIS) of DST, GoI (http://nstmisdst.org/PDF/directory-of-r-and-d-institutions-2015.pdf); (ii) Using the National Institutional Ranking Framework (NIRF), launched on 29th September 2015, which outlines a broad methodology to rank institutions across the country based on various parameters (https://www.nirfindia.org/Ranking); (iii) Using INI, a status conferred to a premier government education institute in India by an Act of Parliament. INI ‘serves as a pivotal player in developing highly skilled personnel within the specified region of the country/state.’ For this study the data was collected from (http://mhrd.gov.in/institutions-national-importance); (iv) A private university was considered when a university was established through a state/central act by a sponsoring body, for which the data was gathered from CAREERS 360 (https://university.careers360.com/colleges/ranking?page=3); (v) For publications, the research article publication data for HEIs and R&D labs was retrieved from Scopus owned by Elsevier (https://www.scopus.com/). Scopus is the largest abstract and citation database of peer-reviewed literature, scientific research articles, books and conference proceedings. For this study, the authors considered only research article publications:

Patents The raw data for patents (published and granted) of INIs was procured from a well-reputed private firm, Talwar & Talwar (TT) Consultants (http://ttconsultants.com/xlpat-patentsearch-tool.php) located in Mohali, Punjab, India. Search tools used for extracting the relevant data were: (i) XLPAT owned by TT Consultants (http://ttconsultants.com/xlpat-patent-searchtool.php); (ii) InPASS of Govt. of India (http://ipindiaservices.gov.in/publicsearch); (iii) Orbit owned by Questel (https://www.questel.com/) (iv) Dervent Innovation owned by Clarivate Analytics (https://clarivate.com/products/derwent-innovation/).

It is encouraging to note that only patents granted have been considered in the study. This study should have incorporated a brief about Prior Art Search methodology and the organizations as to where they are conducted for the benefit of users. Also, not much information has been given about publications from fisheries and naval research organizations.
Chapter VI Recommendations about strengthening the patent regime are well-collated (research should be for human good), but it is not always possible to develop products instantaneously. One needs a much bigger budget than what has been pointed out in the document.

Lastly, the remaining three chapters, including an annexure, provide the details of the classified patents based on international classification; and the recommendations to strengthen the patent regime in India. These are compiled well and provided with future direction. The compilation of this document with the support of DST, GOI, which has been acknowledged, is bound to pave the way for future updates from time to time for the benefit of researchers in the country and provide additional inputs in areas uncovered here, encouraging the scientists and organizations to proactively participate in the process of protecting the intellectual property generated within the nation.
Gender and Sexual Harassment in Science, Technology, Engineering and Medicine: A New Report

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This is not intended to be a book review. Instead, it is a comment apropos of the June 2018 publication of a study report titled ‘Sexual Harassment of Women: Climate, Culture, and Consequences in Academic Sciences, Engineering, and Medicine’ released by the National Academies Press, USA (2018). Soon, some so-called ‘elite’ science journals took note of the report and gave it a good amount of publicity. While there was some discussion internationally about the contents, context and relevance of the subject matter of the report, there was hardly any coverage in India, either in the general press or in the science journals. Around the same time, Tole and Shashidhara (2018) wrote an article, published in Current Science, reporting the proceedings of a meeting, which primarily focused on sexual harassment [SH] in academia and its many shapes and guises. Both reports highlight the critical issue of SH in the workplace.

The 310-page report from the USA is an outcome of intense work from a team of women covering many disciplines. They base their observations and recommendations not only on already available data but also on data from surveys they commissioned. It is a well-researched document and a well-organised one. The report has seven chapters that cover different aspects regarding sexual harassment at workplace. The final chapter comprehensively summarises the findings, provides conclusions and makes recommendation. What lessons can be drawn from this report, on the more specific backdrop of the article from Tole and Shashidhara (2018)?
Women in STEM, Perceptions about SH: The Indian Picture

First, let us take a look at the deeper Indian background; what kind of data, background information and legal framework are available in India? The Indian Women Scientists’ Association (IWSA), founded in 1973, is one of the oldest associations of women scientists. While the association still exists, not only is it unclear what its current level of activity is, it is uncertain how much IWSA has ever considered the rights and equality of its members among the science community as its core mandate. Women physicists and mathematicians from India have been a severe minority. Even before women biologists or physicians started worrying about any discrimination, women physicists had started coming together, in most instances to seek entry for more women in the field and once there, for treating them as professional equals. There does not appear to have been a specific focus on gender-based workplace harassment, particularly SH. Whether it was intended or not, the lack of focus on SH is easy to understand, since talking about harassment at the same time as fighting for entry to the field was likely to backfire. Also, part of the ‘normal’ upbringing in all patriarchal societies is that women are expected to tolerate and ignore, as far as possible, all discriminatory behaviour from men. This cultural imprinting of victims can quite conceivably lead to women themselves not treating SH as a major problem. Also, opening up career opportunities after entering the educational system, at last, would quite understandably seem more important than complaining against SH, especially when men dominate the fields in key positions of power. Thus, in many places in the world, including in India, women have pushed for career advancement quite strongly over the past many decades but have not spoken out strongly against the injustice, subtle and overt, they face in the form of sexual or gender violence.

Some efforts have been made to collect data to evaluate the status of women in STEM in India. However, these are mostly sporadic cross-sectional data collection efforts of modest scale. For example, the Indian National Science Academy (INSA), New Delhi, had constituted a panel of scientists to look at the status of science careers for women in 2004. The Indian Academy of Sciences (IAsc) had established a committee on Women in Science in 2003 which still continues to function. Both these academies have published information in the form of specially commissioned surveys, reports, a compilation of autobiographies and the like and have made recommendations to improve the professional status of women in science. There was also a taskforce on ‘women in science’, set up directly by the Government of India (GoI) and operationalised via the Department of Science and Technology (DST). These and similar efforts have been focussed on encouraging women to stay in the scientific profession where they have spent years in acquiring skills, be it as physicians, engineers or scientists. Unlike in the US or some other countries, public sector salaries are not negotiated in India and hence one clear point of discrimination observed by many women scientists in some countries, that of getting lower salaries than male colleagues, has never been a focus in Indian recommendations. Instead, the recommendations call for options to work from home, better creche facilities, better toilets, proper maternity leave, and the like. The various impacts of the numerically overwhelming presence of men in the workplace, especially in positions of power, are hardly ever mentioned. It remains a common experience that most women scientists are
reluctant to bring up SH at the workplace as a problem that exists and needs redressal. The reasons could be, as mentioned above, that they do not think of it as a serious problem; or that they do not want to rock the boat by bringing it up; or that they are worried about the emotional, social and professional consequences. Whatever be the reasons, the fact remains that we, men or women, have generally not acknowledged that for a healthy pursuit of scientific professions, good productivity and best possible utilisation of the competence of women in the professions, it is necessary that the environment they work in should be conducive to work, should be non-threatening and non-discriminatory.

Women’s movements in India, on the other hand, have consistently highlighted sexual violence, which includes rape and domestic violence as well as workplace SH, as a major discriminatory factor in women’s lives. It was primarily due to the movement that the Supreme Court of India provided a set of procedural guidelines under what is commonly known as the ‘Vishakha Judgement’ in 1997 for cases of workplace SH. While these guidelines provided the basic framework for investigating cases of SH, a law was introduced more recently [The Sexual Harassment of Women at Workplace (Prevention, Prohibition and Redressal) Act, 2013]. Any case of workplace SH, in academic institutions, universities, public hospitals or anywhere else, now comes under this law.

How does the US National Academy Report Contribute to Change?

Both the Vishakha Judgement and the subsequent law are limited in their effects in the absence of a change of mindset in the community, including the scientific community. Therefore, a lot needs to change for the recognition of SH in the workplace, for men to realise that their behaviour can be construed as threatening and harassing. This, of course, is true for any change to become a societal norm. What lessons does the US National Academy report hold for us in India?

The US report provides a great deal of data regarding the contours of SH in the workplace. Such data are useful in the long run for measuring progress. Sadly, progress in this situation will likely be slow in any case. There is, however, a lot to learn from the report in terms of what constitutes workplace SH and what measures would be useful in dealing with it. The report talks about the most common form of sexual harassment as ‘gender harassment’, defined as,

‘...verbal and nonverbal behaviours that convey hostility, objectification, exclusion, or second-class status about members of one gender’ [p.28]

‘behaviors that communicate that women do not belong or do not merit respect’ [p.49].
The report also says coercive sexual attention is not experienced by women without simultaneously experiencing other gender harassment. Essentially the report makes a major point here by showing the connection between the individual problem and the systemic problem in workplace SH. This is important because it is a common notion that women who experience SH are themselves to blame because they wear certain kinds of clothes or behave in a certain fashion thereby attracting men’s attention. While these kinds of arguments can be used as excuses in the blame-game even more acceptable in a strongly patriarchal society, the US and India are not really qualitatively different from each other. However, the possibly greater strength of patriarchal notions in India may well be a contributing factor for not adequate attention being paid to the prevailing atmosphere of gender harassment in the workplace.

What are the changes that this report sees? It points to the ‘MeToo’ movement which has gained momentum from 2016 onwards and brought many women to acknowledge the workplace SH and violence they faced. Women celebrities, as well as non-celebrities, named the well-known men responsible for the sexual violence. These women had all put up with the sexual assaults for the same reasons mentioned above. Some celebrity men got named, including the current US president. It is interesting that there has been an Indian ‘MeToo’ movement as well. Many anonymous Indian women named and shamed Indian men who, in their eyes, have been guilty of some form of sexual assault. In these particular lists, which have steadily grown in numbers, very few men from the STEM fields were initially named. However, this movement seems to have given courage to many women in STEM to say ‘me too’ and to indicate that they had also experienced sexual innuendos or more aggressive forms of sexual assaults from men at their workplaces. Naming and shaming, the strategy of the ‘MeToo’ movement, has its pluses and its minuses; many people, especially the named men, feel that they do not get a chance to defend themselves. This is a common objection to many laws that are aimed at protecting women, and women’s movements all over the world acknowledge and accept the various versions of this so-called problem as a limitation. One wishes that at some point in future these women-centric laws can become redundant.

In the context of SH at the workplace, one point deserves further mention. There are even more vulnerable groups at risk from SH in the workplace than women in general. Women from underprivileged caste, religious and ethnic groups are even more vulnerable to sexual assaults than upper-class, upper-caste, majority-community women are in India. And all available data show that people who live outside of the heteronormative framework of sexual relationships are even more vulnerable to sexual assaults.

It is interesting and instructive that these special vulnerabilities do not find any mention even in the recent article by Tole and Shashidhara (2018). Yet, the Tole and Shashidhara article is unusual in the Indian context. It comes from the Young Investigators’ Meeting [YIM], which celebrated its 10th year in 2018. The YIM is remarkable in the sense that YIM meetings, held mostly around 8 March, International Women’s day, have always had a session on women in science. However, the article from Tole and Shashidhara suggests that a lot more got said about workplace SH in the 2018 YIM than in any other previous YIM. Being able to discuss gender and sexual harassment at the workplace as a problem so openly in a meeting of
scientists is a distinct step forward. Whether it will provide entry points for further discussions and steps towards prevention of SH and punishment of the guilty still remains a question.

The Way Ahead?

Evidence over the last few decades from all over the world has shown a steady increase in the frequencies and numbers of women entering STEM areas and continuing their careers. It is time to pay attention to the quality of the atmosphere these women work in and the need for action to improve that atmosphere. The atmosphere is created by the people who work in these places and men-in-power still remain in the majority in practically every discipline in STEM. Particularly in the Indian context, the problem of gender and sexual harassment at work, including in STEM workplaces, needs to be acknowledged by men. The US report, too, points out, based on its survey using a detailed questionnaire,

‘…male colleagues were unaware of the pervasiveness and severity of sexual harassment experiences in their workplaces. Women described how their colleagues’ gender protected them from experiencing sexual harassment themselves, which made it appear to them as though such harassment did not exist.’ [p256]

More problematic but still possibly useful, the ‘naming and shaming’ strategy used by ‘MeToo’ movements is likely to be increasingly used at the workplace. As the US report says,

‘…their peers and other bystanders can play a strong role in preventing sexual harassment and gender discrimination by acknowledging the inappropriate behavior and indicating disapproval of it. Because this type of behavior can be dismissed or ignored, simply pointing it out can be empowering and lend support to the target.’ [p261-262]

A related insightful comment from one of the respondents in the survey was,

‘The combination of men’s overrepresentation in leadership positions and their lack of awareness of sexual harassment had a powerful stymieing effect on prevention or response at many institutions….If you’ve never been discriminated against, you don’t understand discrimination.’ [p257]

This poignant reality applies not only to gender discrimination but to the equally common Indian situations of discrimination on the basis of caste or religion. As a result, institutional leadership tends to be insensitive to these problems, contributing to the uncomfortable workplace atmosphere that forms part of gender harassment.
The US NAS report makes detailed recommendations for clear broad guidelines that are mostly applicable outside the US as well. However, a circular component of the problem is that these recommendations frequently end up falling on deaf ears in the absence of a gender-sensitive environment. It is to be hoped that men in positions of STEM authority and power will address all these SH-related issues substantively, rather than simply creating the formal illusions of due process.

In March 2016, the Department of Science and Technology of the Government of India notified the constitution of a Standing Committee for Promoting Women in Science. The first term of reference for this standing committee is ‘Make endeavours for creating gender-enabling environment in S&T institutions.’ Increasing awareness of gender and sexual harassment in S&T institutions in India is obviously a prerequisite for this mandate. Since this is the only formal committee currently expected to deal with problems of women in science, it is to be earnestly hoped that it will take note of the US NAS report and the Tole and Shashidhara article and will recommend concrete measures to ameliorate gender and sexual harassment in the STEM workplace.

References


COMMENTARY

Sexual Harassment in Academic Sciences, Engineering and Medicine: A Report

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The growing incidence of sexual harassment in the United States in academia is alarming. More so, as an increasing number of women are entering various science, engineering and medical establishments as students and faculty. Given the increased incidence of sexual offences, the findings of this Report gain universal relevance, in STEM institutions in particular.

The organization of the content in the Report is intermittently repetitive yet neat. Defining what sexually harassing behavior is, forms the beginning of the Report. Then the Report describes the methodological challenges in gathering credible evidence to comprehend (i) the prevalence of sexual harassment experiences; (ii) experiences of sexual harassment among ‘non-majority members of a given workplace or campus’ (p. 33); (iii) legal remedies available, especially the hiatus between what law states and how people comprehend it; and, (iv) the characteristics of sexually harassing environments. An important chapter on ‘organizational climate’ discusses ways to determine whether sexual harassment is likely to occur in a work setting (Chapter 6) and suggests ways to improve the environment. (Appendix C of the Report provides details of a qualitative study of sexual harassment in Science, Engineering and Medicine and can be referred to in this context).
Defining sexual harassment as a form of discrimination, the Report emphasizes and differentiates such behavior into three categories. These include: (i) **gender harassment** (verbal and non-verbal behaviours that convey hostility, objectification, exclusion or second-class status about members of one gender); (ii) **unwanted sexual attention** (verbal or physical unwelcome sexual advances, which can include assault), and (iii) **sexual coercion** (when favourable professional or educational treatment is conditioned on sexual activity) (emphasis as in the original text). These behaviours, according to the Report, can be direct (targeted at an individual) or ambient (general level of sexual harassment in an environment).

The Report provides elaborate details of how these behaviours play out on the ground (among students/faculty in academic establishments). More importantly, it offers a scathing critique of how educational institutions have allowed themselves to be perceived as ‘permissive environments’ where sexually harassing behaviour is not just ‘not contained’ but in fact, very often, normalized. To quote the original: “when targets report, they are either retaliated against or nothing happens to the perpetrator” (p. 51); “The interview responses demonstrate that the behaviour of male colleagues, whom higher-ranking faculty or administrators perceive as ‘superstars’ in their particular substantive area, were often minimized or ignored” (p. 51); “The normalization of sexual harassment and gender bias was also noted as fueling this behaviour in new cohorts of sciences, engineering and medicine faculty” (p. 52).

The Report alludes to the ‘culture’ of higher education workplaces which promotes the notion of an ‘ideal worker’ or in other words, someone who works fulltime and consistently over a lifetime and avails no leaves for maternity, child care or other care-giving responsibilities (p. 54). The message thus sent out is that women who disproportionately bear these responsibilities ‘do not belong here.’ The ‘ideal worker’ norm also indirectly contributes to perpetuating the perception of women not being as capable and competent as men are. Several respondents considered such gender-based harassment far more pernicious to their functioning and well-being than harassment in the form of unwanted sexual advances.

Significant power differentials between mostly male-dominated gender ratios and leadership within hierarchical organizations are fertile environments for sexual harassment. The Report nevertheless points out that “sexual harassment can be bottom-up, coming from those who have less formal power in the organization; researchers often refer to this as contra power harassment” (p. 56–57). Further, the Report notes that, among science, engineering, and medicine disciplines, female students in **academic medicine** experience more gender harassment by faculty/staff than female students in science and engineering. Worse, women students, trainees and faculty in **academic medical centres** experience sexual harassment by patients, and patients’ families in addition to the harassment they experience from colleagues and those in leadership positions (emphasis by the author of this article) (p. 63).

Chapter 4 of the Report describes the disturbing outcomes of sexual harassment experiences. The Report states that women’s experiences of sexual harassment result in jeopardizing their professional, psychological and physical health. The outcomes remain significant even when controlling (1) the experiences of other stressors, (2) other features of the job, (3) personality, and (4) other demographic factors (p. 68). To elucidate further, the Report argues that the links
between sexual harassment and declines in psychological and professional well-being remain robust even when other stressors such as general job stress, trauma outside of work, etc., are taken into account. Similarly, the results remain significant when other features of the job such as organizational tenure, workload, etc., are taken into account. Again, personality related factors such as negative affectivity, neuroticism, narcissism do not take away the significance of sexual harassment outcomes. Demographic factors such as age, educational level, race also do not fully explain the declines in psychological and professional declines. In other words, the adverse impacts of sexual harassment remain significant even after controlling the four factors mentioned above. ‘Professional Outcomes’ is defined as ‘organizational withdrawal’ by the sexually harassed person, which is further categorized as (i) work withdrawal (distancing oneself from the work without actually quitting – absenteeism, use of sick leave, etc.), and (ii) job withdrawal (intentions to leave their jobs and organization itself, among others) (p. 70). The Report also lists the tangible and intangible losses that women suffer due to sexual harassment. Tangible losses include the loss of job (for being labelled as a complainer and troublemaker) and the associated loss of financial, personal and social benefits. Intangible losses include the loss of self-esteem, self-confidence, and motivation or passion for work (p. 74).

There is a need for further research to capture the differential impacts, if any, of women of colour as well as of sexual-and gender-minority individuals, often overlooked groups, admits the Report. It further alludes to the “generally hostile environment for this population, ranging from coming-out stress to using the wrong pronouns, to accessibility to safe bathrooms, which suggests it is important to study sexual harassment in this population to see how it may intersect with other forms of harassment (such as heterosexist harassment and transgender harassment) and incivility,” quoting existing research (p. 78).

“Coping mechanism, formal reporting for targets is the last resort: it becomes an option only when all others have been exhausted” (p. 81). The reasons why reporting sexual harassment was never an easy or first option forms the qualitative part of the study and documents respondents’ own words in detail. The lack of an anonymous or protected channel to raise sexual harassment complaints against a colleague or superior had a chilling effect on all forms of disclosure (p. 254). It was a pervasive perception that university-level reporting mechanisms focused heavily on protecting the institution rather than supporting the target of harassment. Further, the respondents remarked that for certain roles and situations, viz., post-doctoral students or when the victim or perpetrator were at different institutions, there were no mechanisms in place for reporting (p. 255). Sexual harassment at academic workplaces violates research integrity (where the latter relies on a set of ethical principles and professional standards), says the Report.

Six approaches to improve the ambience and culture in higher education were identified by the committee (authors) of this Report. There is a need to integrate the values of diversity, inclusion and respect into policies, procedures, organizational strategies and human resource systems, many of which, according to the Report, "already have problematic norms and values built into them" (p. 125). Women of colour and sexual and gender minorities ‘cannot bring their’ ‘whole selves’ to their work, argues the Report. This forms the backbone of the need and relevance for diversity initiatives in the larger breadth of sexual harassment. Instead, they
must ‘code switch’ while at work – that is, adopt the behaviour patterns, speech, dress and values of the majority group’ (p. 125). Not relenting to switch code could lead to gender harassment, and the constant need to police oneself to switch code could be less productive vis-à-vis professional competence and advancement. Similarly, wherever evaluation and reward structures are focused solely on individual-level teaching and research performance, with no consideration for how respectful and cooperative one’s behaviour has been, could lead to hiring practices that not only take on ‘star performers’ (those who bring in considerable resources) but also protect such ‘stars’ despite it being known that these stars are known, sexual offenders. Comprehending how our society is deeply biased, and how to respond when such biases turn into harassment is another aspect dealt with in the Report. ‘Bystander intervention training’ teaches people how to respond when they witness problematic behaviour (p. 133) and this is an integral part of the Report. Institutions keen on establishing zero tolerance to sexual harassment need to follow-up investigations within a reasonable timeframe. The Report also emphasizes, “The disciplinary action should not be something that is often considered a benefit for faculty, such as reduction in teaching load or time away from campus service responsibilities. In other words, perpetrators should not be ‘rewarded’ for their behaviour” (p. 144). Further research is required to evaluate the various approaches and trainings to arrive at best practices, notes the Report.

Undoubtedly, this Report makes a seminal contribution to our understanding of how sexual harassment is not just a gross violation of human rights but one that is fraught with deep adverse consequences for those who are targets of such harassment. The Report becomes all the more important when posited against attempts to involve more women and members of minority communities into higher education institutions of science, engineering and medicine. Even when in a different geographical context, countries across the globe can learn much from this Report.

A couple of observations that a close reading of the Report raises: One, over a long period, and including in the United States, courses in Women’s/Gender Studies, and the institutionalization of Women’s/Gender Studies as a discipline has enabled non-STEM educational institutions to initiate and carry on continuous conversations and actions around the broad theme of gender-based violence. While the Report alludes to non-STEM initiatives in passing, it does not elaborate on why the authors of the Report have not drawn from the experiences of non-STEM institutions. It is also not clear from the Report whether such efforts to engage with non-STEM institutions were made, and if so, with what effect. The review of literature done by the Report under consideration also does not mention whether it actively searched for studies that have dealt with sexual harassment issues in higher education institutions in general and that cover disciplines other than STEM. Two, throughout the Report, an observation that stands out is that academic medical institutions are far more prone to sexual harassment than academic science and engineering institutions, with targets in medical institutions even feeling unsafe in their places of work. It is not very clear from the Report whether, after realizing this fact of academic medical establishments being more prone to sexual harassment, efforts were made to find out what is it about medical establishments that makes them particularly pernicious places of work. Three, a profitable way to carry forward the mission begun by the Report, namely, ‘Changing the Culture and Climate in Higher Education’ could be to first explore what is it about the syllabus and contents of the
existing STEM courses that contribute in no small measure to the production of the pernicious environment sketched by the Report.
Remembering Debiprasad Chattopadhyaya’s Contribution to the History of Philosophical Thought and Scientific Ideas on His Birth Centenary

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Abstract

Lokāyata is considered Debiprasad Chattopadhyaya’s magnum opus, a pioneering exploration of the history of materialist thought in ancient India. This work not only established his reputation but subsequently provided a rationale for the need to re-position the schools of Indian philosophical thought in terms of their internal diversity, the range of philosophical problems addressed and the ‘family resemblances’ between the schools. He subsequently went on to pursue the study of the beginnings of scientific thought in ancient India between the period of what historians call the two urbanizations. On his birth centenary, this essay explores the issues discussed in his work, the reception of his ideas amongst historians of science, and their contemporary salience.

Keywords: Ancient India; materialism, idealism, urbanization, scientific thought.

‘...irreverent defender of the best in the Indian tradition’ (Ramakrishna 2017)

More than two decades have gone by, and yet it appears not too long ago that my colleague S. Irfan Habib and I had our last animated discussions with Debiprasad Chattopadhyaya (1918–1993). The arrival of his birth centenary is a reminder of the different rhythms of time and memory. I had the good fortune to have met him on many occasions between 1984 and 1993 on his visits to Delhi as a Guest Scientist associated with NISTADS. My exposure to the work of Debiprasad Cattopadhyaya [hereafter Debida] came from what might appear unlikely sources and commenced with his book on Indian Atheism. Although my work focuses on a later period of South Asian history, I have had to return to his substantial oeuvre whenever questions of the historiography of the sciences of South Asia arise.

This essay attempts to trace in brief the evolution of his work from the publication of his magnum opus Lokāyata to the history of sciences, while a more detailed review needs to be undertaken. As a student of philosophy in Kolkata, his teachers included leading Indian philosophers such as Surendranath Dasgupta, S. Radhakrishnan, Humayun Kabir, Sukumar Sen and many others. During the late 1930s he came under the influence of Marxist theory through his interactions with scholars that included Bankim Mukherjee, Radharaman Mitra and was mentored in the early years by Samar Sen. However, his career took a turn when he went to London in 1950 to work at the British Museum. There he met George Thomson from whom he acquired the disciplinary tools for the study and interpretation of totems in ancient societies. Thomson was the author of the classic Studies in Ancient Greece: The Prehistoric Aegean. Though trained as a philosopher, Chattopadhyaya began to draw upon the methods and insights of anthropologists and archaeologists. The outcome of the time spent at the British Museum was Lokāyata, the first of his books to highlight the existence and significance of materialist thought in ancient India, that he subsequently elaborated upon in several other works such as Materialism in Ancient India, Two Trends in Indian Philosophy, What is Living and What is Dead in Indian Philosophy and A Popular Introduction to Indian Philosophy. The task was a difficult one because there was no textual source explicitly dedicated to the subject. The challenge was to consolidate our understanding of the materialist school from stray references in the Mahabharata, Arthashastra, and allusions in works from the other darsanas. Chattopadhyaya subsequently went on to publish three volumes on the history of science and technology in ancient India, not to mention a substantial corpus of writing in Bengali on science, history and literature [Acharya 2017].

More specifically, this was reflected in his struggle to make sense of a passage from the Chandogya Upanishad, where anthropology came to his rescue in providing a new reading. As G. Ramakrishna, a close associate and collaborator for many years points out that Debida traced the names of many of the seers mentioned in the Rg Veda to their totemic names such as Kashyapas, Mandukeyas, Shaunakas, Kaushikas [Ramakrishna 2015].
The following paragraphs make a modest attempt to situate this corpus of writing in the light of the historiographic revolution that globally marked the history and philosophy of science since the 1980s [Harding 1998] (or HPS as the interdisciplinary field is designated) as well as the reception of his work within the larger corpus of the history of science in South Asia – again a domain of research that has exploded over the last two decades both in India and abroad [Habib and Raina 2007]. In other words, where does this body of work stand in relation to the developments in postcolonial studies of science and technology? It is not likely that justice will be done to all these issues, but this could be seen as travail en cours.

Within the world of HPS scholarship on South Asia, if one encounters little discussion today among researchers about the work of Debiprasad Chattopadhyaya then this is attributable in part to the eclipse of the Marxist imagination and its methods, tasks and goals by a post-industrial knowledge economy. A second development possibly explains the lack of engagement with this important corpus of scholarship. Most effort over the last fifty years in the history of sciences in South Asia has been devoted to a fairly recent segment of its history, basically addressing the period of colonial rule and extending backwards perhaps a century or so into the pre-colonial period. While this work into the politics of knowledge has been very insightful it has drawn more on post-structuralism and its social theoretic resources, to the neglect of the older Marxian tradition. But more importantly, it has posed a major challenge to Eurocentrism in history and theory or what Sandra Harding referred to as the ‘integrity of modern science’ [Harding 1998; Raina 2003]. As a result, the study of the social history of science in ancient India has indeed been neglected [Raina 2015].

A cursory inspection of the complete writings of Chattopadhyaya would indicate that his attention perceptibly shifted from the history of philosophical thought to the history of sciences in the 1970s- but the two domains remained comprehensively and conceptually entangled. The philosophical work endeavoured to substantially elaborate upon the idea that the Indian philosophical tradition was rich and diverse but had been over characterized by the late nineteenth and early twentieth-century philosophers as solely idealist and transcendental. The publication of Science and Society in Ancient India in 1977 marked the shift to the study of the history of sciences [Chattopadhyaya 1977]. In 1982, History of Science in India appeared in 2 volumes [Chattopadhyaya 1982]. These were edited volumes comprising classics and highly cited articles authored by Indologists and by other scholars from different parts of the world on diverse aspects of Indian science and culture over historical time. Several of these articles had been published in the nineteenth century and as many were of a more contemporary provenance. The volumes dealt largely with the sciences in ancient India, with two papers by A. Rahman and Irfan Habib dealing with science and technology during the medieval period [Chattopadhyaya 1982 vol. 2]. Colonial science was clearly not an issue he addressed. The first volume covered philosophy and science, raising issues of the nature of science in ancient India, the elements of atomistic thought and causal thinking – both essential to any argument for the existence of protomaterialism as well as on the scientific method [Chattopadhyaya 1982

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[3] Chattopadhyaya was also assisted by and collaborated with the Sanskritist and Nyayika Mrinal Kanti Gangopadhyaya whose response to Vedanta was that of a Nyayika. The latter went on to author several works on the history of Indian philosophy.
vol. 1]. The rest of the book dealt with papers addressing the history of medicine, alchemy, chemistry and botany. The second volume had a comprehensive collection of papers on the history of astrology, astronomy and mathematics including the classics by Thibaut, Sengupta, Colebrooke, Datta etc.; followed by a section on interaction and exchange [Chattopadhyaya 1982 vol. 2].

One could look at the publication of these volumes as preparatory for the volumes that were published under a NISTADS supported project a couple of years later. This last decade was devoted exclusively to the study of the history of sciences in ancient India and though he worked out of Kolkata, he began visiting New Delhi often and entered into discussions with a younger generation of scholars in New Delhi. In 1984, NISTADS organized an important workshop on the history of sciences to commemorate its foundation. The proceedings of the workshop appeared as Science and Technology in Indian Culture: A Historical Perspective [Rahman 1984]. Not all the papers appearing in the volume were about the history of sciences, but Chattopadhyaya’s paper entitled ‘Science in Ancient India; Materials for Reopening Some Old Questions,’ set the tone for the massive project he had just embarked upon.

The first of the publications of the project on the History of Science and Technology in Ancient India: The Beginnings appeared in 1986 [Chattopadhyaya 1986]. The core of the book dealt with material culture between the period of the two urbanizations. This broad exploratory attempt sought to pin down the manifestations of science between the urbanization dating back to Harappa and Mohenjo-Daro and the second urbanization of the Mauryan period. Only Chapter 13 that dealt with the linguistic and oral traditions during this period was authored by the recently deceased Navjyoti Singh. The other chapters dealt with the beginnings of material culture – metal technology, pottery, textiles, transport etc.- from the first urbanization and the relationship between material culture and the first appearance of conceptual categories representing the rudiments of scientific thought and practice. The second volume appeared in 1991, and this was subtitled Formation of the Theoretical Fundamentals of Natural Science [Chattopadhyaya 1991]. This work begins with a discussion of the emergence of the different philosophical schools, the conceptual vocabulary of the schools and their progression towards scientific thought followed by a chapter on medicine and magic during early antiquity. This discussion is elaborated in nine chapters followed by ten appendices comprising articles of historians, including some classic articles and expositions of ancient Jaina logics or Syadvada in contemporary terms – authored by leading scientists such as the biologist J.B.S. Haldane, the astrophysicist D.S. Kothari, etc. A third, slim volume published posthumously, dealt with astronomy, science and society in ancient India [Chattopadhyaya 1996]. This must have been envisaged as a larger work but was not to be.

Regarding the organization of the chapters and the orientation of the work, I have discussed the influence of Needham’s volumes on Science and Civilization in China on

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[4] The book was reviewed by Robert Temple in the journal Nature in 1991, where he remarked rather prophetically that the book `...grapples directly with the issue whether India is to have any future or not. Chattopadhyaya is a brave man, and he has tackled the fundamental problem head on; he shows the history of Hindu obscurantism that has oppressed the rise of science in India through the ages; [Temple 1991]. But there were many critical reviews of the book as well.
Chattopadhyaya’s project in my Needham’s Indian Network [Raina 2015]. This influence I have tried to trace in the chapter of the book on ‘The Marxist History of Science,’ where his work is discussed alongside that of Irfan Habib, D. D. Kosambi and Abdur Rahman. But the influence of Needham can be identified at several levels. Departing from the Eurocentric frame of the history of science, Science and Civilization in China itself became both an icon and an exemplar to be replicated in Asia and the Arab world and nations liberated from the yoke of colonial rule. The work inspired several national and civilizational projects on the history of science particularly during the first decade of decolonisation [Raina 2015]. Secondly, in the comparative context, Needham provided a template for benchmarking developments in China vis-à-vis European developments and thereby provided analogies and exemplars in the Kuhnian sense for framing and unpacking the evolution of science in India [Raina and Habib 1999 ]. Clearly, comparative history provided a key for investigating the history of sciences in these other regions. And lastly, Needham’s methodological Marxism provided a bonding for scholars so oriented from across the globe, who shared the image of science as a cultural universal and for what one of Needham’s collaborators, the global historian Gregory Blue called epistemological egalitarianism [Blue 1999].

In a Preface to a posthumously published work, Prof. Ramakrishna Bhattacharya points out the several influences on Debida’s work [Chattopadhyaya 2013]. I have been following the influence of three scholars - Walter Ruben, P. C. Ray and Joseph Needham on Chattopadhyaya. As hinted in my book Needham’s Indian Network, I was fortunate enough to meet the students of the German Indologist Walter Ruben and trace some of their correspondence [Raina 2015]. All three had substantial contributions to make in the discussion on science in the ancient world – Needham focussing upon China; Ruben himself as a leading German Indologist had contributed extensively to the study of ancient India, but in this specific context we need to mention his particular focus on hylozoism in the early Upanisadic literature that inspired Chattopadhyaya’s reading of Uddalaka Aruni as the first Indian empiricist; and Acharya Prafulla Chandra Ray provided the template for looking at the relationship between alchemy and tantric knowledge, the relationship between artisanal and tribal knowledge with Ayurvedic pharmacology. The important point that Ruben was making and that was elaborated upon in Lokāyata and other works was the recognition of the archaeological layers in the Upanishadic corpus, and of the several strains of thought present within it. G. Ramakrishna remarked that the Lokāyata ‘…catalogues the variety of forms in which materialist thought expressed itself and the way it evolved through the ages...The customs and modes of worship in the form of rituals have evolved likewise - these served as an embryo for later manifestations of materialism’ [Ramakrishna 2017, p. 19]. Chattopadhyaya designated these forms of materialism as proto-materialism. In fact, the standard classification of the different darsanas or schools of Indian philosophy is questioned and a family resemblance between Sāmkhya, Vaishesikha, Buddhism and the Lokāyata is recognised, leading Chattopadhyaya to argue for a different classification rather than one based on Vedic authority. For philosophical purposes, this classification would be derived from how the schools thought about objective reality and subjective consciousness [Ramakrishna 2017 p.22].
Furthermore, he was a member of a ‘visible college’ of researchers – call them the Needhamians – which included J. D. Bernal, physicist, science policy analyst and author of the popular *Science in History* and the bible of Science Policy namely *The Social Function of Science* [Bernal 1939; Bernal 1954]. As pointed out in an article a colleague and I wrote several decades ago, within these networks the influence of Bernal’s *Science in History* was more widespread within the low church of science studies, for reasons that are detailed in the review Jerome Ravetz did of the book - two of which being that the work was possibly outdated by the time it was published. Secondly, despite Bernal’s brave effort it could not overcome its Eurocentric premises [Ravetz 1992; Raina and Habib 1999]. Needham’s ecumenical history of science had taken the first step in that direction, but even that was problematic although it was the first step all the same. ²

In short, an inventory of Chattopadhyaya’s contributions would include the history of sciences in the Indian tradition, technological skills in ancient India, the history of philosophical thought, the history of Ayurveda, Marxist theory, the history of folk traditions and the popularization of the sciences - mention must also be made of the books he wrote for children. This enormous corpus of writing sought to present the different streams of materialist thought in the Indian tradition. Though other scholars had presented Vedanta until the first half of the twentieth century as the crest jewel of Indian philosophy, it was now argued that Indian materialism was a viable philosophy for scientists as much as for the toiling classes. ³ Though he chronicled in detail the marginalisation of materialist thought in Indian philosophy, he argued that this primitive materialism had left its signature in the folk traditions [Ramakrishna 2017 p.19].

We return to the initial concern with the reception of this immense body of work in his time and its salience to contemporary trends in the history of science. In other words, the question posed is the following: what has survived the juggernaut of the world of intensified and highly institutionalised domains of knowledge production? What is it that has been surpassed by the changing frames and metanarratives of history and what is in need of revision? This is what we can ask of his scholarly contributions over a period of half a century. Let us begin by recapitulating a point made earlier, namely that the field of the history and philosophy of science underwent a formidable upheaval first with the historicist turn in the philosophy of sciences ushered in by the critiques of both positivism and the Vienna circle, and subsequently spearheaded by the work of Popper, Kuhn, Lakatos and Feyerabend [Newton-Smith 2000]. This radically revised both the philosophy of science and imparted a new self-confidence to the philosophy of social sciences. In the process, these developments destabilised the pre-Cold War and Cold War imaginary of science [Fuller 1997; Dennis 1997].

This transformation prepared the way for the emergence of the social turn in the form of the ascent of the sociology of knowledge and epitomised in a cognitive movement referred to

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[²] For a detailed discussion on the same see the essays in Raina and Habib (Eds), *Situating the History of Science: Dialogues with Joseph Needham*, 1999.

[³] In the second half of the twentieth century, other Indian philosophers too began to revisit the central questions and concerns of Indian philosophy – shifting the focus of interest from Vedanta, for example, to problems of philosophical realism etc. These philosophers included P.T. Raja. Daya Krishna, B.K. Matilal, J.N. Mohanty too name a few.
as social constructivism or the social construction of scientific knowledge [Bloor 1976, Knorr-Cetina and Mulkay 1983]. What did this mean for the history of science? As far back as 1931, the Marxist history of science had announced its arrival at the IUHS conference held in Cambridge [Chilvers 2003]. The Cambridge left consolidated itself around this historiographic conjuncture – Joseph Needham, J. D. Bernal, J. B. S. Haldane and others. We do know that Debida had an active correspondence with two of these three members of the Cambridge left – namely Needham and Haldane. The Marxist history of sciences was premised on a clear-cut distinction between the internal conceptual core of science and the external context of science that provided a medium for the emergence of science or obstructed its development [Werskey 1978]. The boundary between the two was not permeable; and this distinction ensured the universality of science, that scientific concepts and theories transcended cultural context – that science was a cultural universal [Cunningham and Williams 1993]. Gary Werskey, author of The Visible College presented a paper at the IUHS Congress held in Beijing in in 2005, where he argued that by refusing to confront the internal-external dichotomy Marxism could not radicalize itself [Werskey 2007].

Inspired by the work of Karl Mannheim, and Wittgenstein of the Philosophical Investigations the new sociology of knowledge redrew the boundary between the external and the internal, postulating something that may have been blasphemous to the old Marxist philosophy of science, namely that the internal core of science was socially conditioned. This recognition transformed an impermeable boundary into a more porous one [Bloor 1976]. Universal knowledge now became situated knowledge, and the positivist conception of science was outflanked by a contextualist theory of knowledge. It took philosophically predisposed sociologists some effort to explain why contextualism did not breed relativism, and thereby arrested the collapse of contextualism into relativism. One could not have been a student of the history and philosophy of science through those decades and been immune or indifferent to these developments. These developments posed a serious intellectual challenge for Marxism and its different Marxologies and a great deal of conceptual work had to be done to engage with these issues in other fields as well [Chibber 2013].

Chattopadhyaaya completely sidestepped these concerns or preferred to remain silent. S. Irfan Habib and I in 1991 or 1992 asked him what he thought of these developments that had so deeply engaged our energies and he said that he was not a historian of science in that sense, but was in intellectual combat with the recidivist and upper caste reconstructions of an imagined Indian past. By the 1980s and 1990s, the landscape of social science research had changed and there was a radical critique of science and the enlightenment project that captivated the new generation of social scientists [Fuller 1993]. Yes, there was a paradigm shift and it was the older generation that continued to be drawn towards the concerns that animated Lokāyata and related writings. The next generation had moved on in terms of their
concerns and methodologies even as these volumes on the history of sciences of ancient India were published.

Two conceptual dichotomies that appear in his work were being thoroughly examined during this very period and that altered the terms of discussion in the philosophy of science. These were «religion – science>> and «idealism – materialism>>. In Chattopadhyaya’s view what brings Shankara and Plato together is the ideological convergence between the denial of the reality of the physical world and the viewpoints of the lawgivers. And though Ramanuja and Madhava did accept the reality of the external world their viewpoints were not too distant from that of the conservative lawgivers [Ramakrishna 2017, p. p. 30–32]. The premise underlying this dichotomy was that the roots of science in India as in other parts of the world were in materialism.

The enormous amount of work that went into the history of science during the immediate post World War II years was beginning to produce a major transformation of the field. The philosophers had already posited that the philosophy of science without the history of science was empty [Lakatos 1978]. In addition, while trained physicists continued to jump into the field, by this time trained historians were the newcomers. As early as 1937, the sociologist of science Robert K. Merton had submitted his doctoral thesis on English Protestantism and the Rise of the Sciences, which had already begun to reshape our understanding of the relationship between science and religion that was hitherto considered to be an antagonistic one. Merton’s work suggested that both in the case of German Pietism and English Protestantism, the Protestant ethos provided an appropriate medium for the emergence of bureaucratic rationality and modern science [Merton 1970].

A couple of decades later even the most powerful origin myth of modern science was rejected on historical grounds. The Galileo affair, in the light of the new historiucal evidence, was far more complex than hitherto portrayed and had more to do with other aspects of his work than with his avowal of heliocentrism per se, the most important consideration was whether he was just proposing a model of the universe or ontologically revising the idea of God’s creation [Drake 1996; Redondi 1987]. As Richard Tarnas points out a grand cosmological compromise was worked out between science and religion [Tarnas 1991]. Galileo as Dava Sobel points out would have been deeply disturbed if he had been accused of being anti-Christian [Sobel 1999]. Similarly, the great Newton, framed by the revolutionary historiography of the eighteenth century as the father of materialism and mechanics, and seen within Marxist historiography as the flag bearer of atheism, was revealed to be both a practicing alchemist and spent the latter portion of his life engaging with a discussion on the Christian trinity [Westfall 1971]. And then in the 1990s Heilbron’s work The Sun in the Church mapped the rise of Jesuit sciences or Jesuit astronomy in particular [Heilbron 1999]. These developments complicated our understanding of the relationship between science and religion rather than the purely reductive one that emerged from formulaic readings of the history of science.

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One could cite any number of scholars whose researches on the sciences of ancient Indian medicine and astronomy is truly encyclopaedic. In passing, we cannot enter the field of astronomy in ancient India without engaging with the work of the legendary David Pingree [Pingree 1978] In like manner, the Indologist Gerrit Jan Meulenbeld’s 5 volumes on the history of Ayurveda are indeed a remarkable contribution to the field [Meulenbeld 1999]. This corpus of scholarship falls squarely within the history of sciences.

[7]

Today the historiographies of `science and religion' offer a nuanced understanding of the relationship between the two and reveal how this is manifested in diverse and complex geographies of knowledge [Brooke 1996].

Where did this historiography of conflict come from and how did it acquire such a hegemonic place in scholarly discourse. The historian of science Rivka Feldhay points out that one of its many genealogies is traceable to the French revolution, wherein the relationship between the monarchy and the Church was different from that in the Protestant countries [Feldhay 2001]. A very specific political and cultural construction of revolutionary France stabilised in scholarly and disciplinary discourses as a deeply antithetical relationship [Cohen 1994]. Chattopadhyaya's reading carried much of the burden of that relationship. However, in all fairness, he was also influenced by Needham's own reading of the relationship between the scientific and the noumenal, and that Needham saw himself as an honorary Daoist [Needham 1973]. As far as the reception of the work is concerned the fine text of Chattopadhyaya's writing on specific historical moments is lost sight off by the broader overdetermined frame of the science-religion conflict.

Despite the passage of time what does remain is his extension of the frame first proposed by P. C. Ray that I somewhere labelled as the proto-Zilsel hypothesis [Raina 1997]. Zilsel's hypothesis appears in his much-discussed work `The Social Origins of Science' and attempts to explain the rise of the modern sciences in 17th century Europe. The explanation offered through a deep historical investigation of the period was that modern science arose at the conjuncture of two traditions, that of technical and artisanal knowledge and practices and that of the theoretical or formal disciplines [Zilsel 1942]. Within the Indian context, Acharya P. C. Ray had proposed a similar explanation for the phenomenon of the non-emergence of modern science – the separation between artisanal and theoretical knowledge due to the proscriptions of caste played a significant role in impeding the development of the sciences [Ray 1902; Ray 1906; Ray 1907]. This hypothesis is elaborated upon in the corpus of Chattopadhyaya's writing, and as every reader can identify, the relationship between theoretical knowledge and tacit, uncodified technical practices is fundamental to his work. This aspect of his work has withstood the logic of development characterising the world of knowledge.

I come now to the second of the dichotomies that could well be seen as the intellectual conflict between idealism and materialism which could be reduced to a conflict of social classes. Here too the history of scientific ideas confirms the hypothesis that science at all times or at any one time is the arena for the unfolding of several philosophical positions, which is what gives rise to competing theories [Lakatos 1978]. The rise of the mechanical worldview did not entail the elimination of the field theoretical notions as Needham appropriately pointed out [Needham 1969]. As far as the rise of the modern sciences is concerned, it is not possible to

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[8] In an oft quoted passage from the History of Hindu Chemistry Ray argued that: ‘...certain forces extraneous to the world of science had stunted the growth of science and scientific endeavours... Such forces were the social order in prevalence which was discriminatory and those who nurtured that order...The caste division in society reduced our artisans, technicians and others involved in manual labour to a lowly position in society. Their dignity was hurled to the winds and their extraordinary abilities were marginalised...This happened after the Buddhists were marginalized and the Brahmans gained ascendancy’ [Ray 1902].
discuss their ascent without referring to the rise of neo-Platonic thinking and the mathematisation of nature [Koyre 1939].

Furthermore, other than the philosophical critique of this dichotomy there is a lesson to be learned from the famous 1931 meeting. At the meeting, Boris Hessen presented his classic paper on ‘The Socio-economic Roots of Newton’s Principia’ that subsequently inaugurated the Marxist history of science [Hessen 1931]. In Loren Graham’s reading of the paper, Hessen was also signalling to the audiences back home in the Soviet Union, that if they considered Einstein’s physics and quantum theory as bourgeois physics or idealist physics, then one has to factor in the rise of Newtonian physics within the larger emergence of the capitalist economy [Graham 1985]. Hessen, as Graham shows was cautioning the Soviet regime that the new physics was not bourgeois physics and cautioning his readership against the strong social conditioning of philosophical and scientific ideas by social class. As Althusser once wrote: ‘Philosophy in the last instance is class struggle in the field of theory’ [Althusser 1971]. The relative autonomy of science in social theory has to be explained by even the most reductive sociology of knowledge.

These ideas echo in Debida’s discussion and there are advantages of not running with the mainstream but running in parallel. But an opportunity is lost in consideration of what the other system anticipated and how one’s own conclusions could measure up to the theoretical gaze of another system. This aperçu has another significance, for if the histories of knowledge have benefitted from the comparative methods employed in studying the past, then comparativism has an equally important role to play in triangulating our contemporary metanarratives. We need to ask ourselves in the second decade of the twenty-first century what is it that we draw into our contemporary discussion and what is it in a Lakatosian fashion that awaits another interpretation.

If Kosambi departed from traditional Marxism by inventing another Marxology, in demonstrating that the evolution of material culture and material cultural practices indicates that India has a history, then Chattopadhyaya extended the argument into the realm of the superstructure by highlighting not just the presence but the development of materialist thought on the sub-continent. The latter ran contrary to the nineteenth-century constructions of India as a spiritual civilization. The discovery of the roots of philosophical materialism was indeed very significant in its own times and continues to do so today, as a counterweight to the distortion of the history of philosophical thought in Indian antiquity. Secondly, while the social theoretic and philosophical developments that I have highlighted might run contrary to some of the core framings of this immense project, Chattopadhyaya would still have concurred with some of the insights of the sociology of philosophy in its version of conflict theory. The history of philosophy like the history of science, like history in general, is a history of contesting ideas and knowledge communities. This conflict in the realm of ideas cannot be reduced to the opposition between rationalism and irrationalism alone. The churchmen who raised objections about what Galileo saw through the telescope were not being entirely irrational – there were also rational and scientific objections [Feyerabend 1975]. This does not deny the existence of irrational forces within society but brackets the rivalry between idealism and realism. Clashes in theory, can extend over a variety of positions, and even so-called metaphysically overloaded theories, as Popper pointed out can over the passage
of time become scientifically falsifiable – and as Lakatos reminds us that even a scientifically progressive programme can enter a degenerating phase. I could not but help remember the discussion on the early Nyāya and the Nyāya after Udayana in the work of Chattopadhyaya.

This body of work maintains its relevance for the rich historical detail that will open itself to radical re-readings of new themes and problematics in Indian philosophical thought in the light of the parallel evolution of social theory and the work of numerous historians and philosophers of science. Philosophers and historians of philosophy have continued to engage with the Lokāyata. Some recent works include Ramakrishna Bhattacharya, *Studies on the Cārvaka/Lokāyata* (2010); Pradeep P. Gokhale, *Lokāyata/Cārvaka: A Philosophical Inquiry* (2015); Bhupendra Heera, *Uniqueness of Cārvaka Philosophy in Indian Traditional Thought* (2011). Debida emphasised a handful of themes which he felt were the central intellectual and political problematics of his generation. But that does not exhaust the richness of his contribution, and it is time to turn back and read him through our contemporary problematics and the lenses of a highly revised social theory and philosophy of science.

In brief, if we were to summarize his intellectual journey, Debiparsad Chattopadhyaya commenced his research career with the study of the origins of materialist thought in ancient India, proceeded to the history of the evolution of the conflict between idealism and materialism, drew out the consequences of this conflict for the history of sciences in ancient India and finally transited to the study of history of sciences and techniques between the two urbanizations. Commencing in philosophy proper, he turned to the study of archaeology and anthropology and then the history of sciences and techniques. In the latter case, he was deeply influenced by the writings of Joseph Needham and P. C. Ray, and finally ended up collaborating with astronomers from Bangalore, introduced to him by G. Ramakrishna in order to embark on a ‘retrospective probing’ of the history of astronomy in ancient India.

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Arsenic Toxicity in Soil-Plant-Human Continuum and Remedial Options

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Abstract

Even though the widespread arsenic (As) contamination of groundwater in West Bengal (India) and Bangladesh has remained mostly confined to the Bengal delta basin, bound by the rivers Bhagirathi and Padma, the spread (detection) of such groundwater arsenic contamination has been reported from several states of India, as well as certain other parts of the Indian subcontinent. The safe limit for arsenic in drinking water has been prescribed by the World Health Organization (WHO) to be 10 μg As. L⁻¹ and yet, arsenic contamination in the groundwater to the tune of 50 to 3700 μg As. L⁻¹ has been reported from the states of West Bengal, Assam, Bihar, Uttar Pradesh, Madhya Pradesh, Manipur, Jharkhand, Chhattisgarh, Punjab, Tripura and Nagaland. The source of such arsenic contamination in groundwater is believed to be of geogenic origin. The primary attention so far has been directed towards solving the problem of contaminated groundwater-based drinking water, notwithstanding the fact that the groundwater in the affected belt is extensively used in the agricultural sector rather than for drinking purpose. The number and extent of well-planned systematic studies conducted so far to examine the influence of arsenic in groundwater, used as irrigation source, on soil-plant-human continuum are only limited. Indeed, much more research work remains to be done in this field, not only in the Bengal delta basin but also, and especially in the other
parts of the affected belt mentioned above. This issue assumes particular significance in view of the fact that what remains essentially a point-source of contamination, as in the case of drinking water, becomes a diffuse-source of contamination of uncertain extent and spread, when arsenic finds its way into the human-food-web through the use of such contaminated groundwater for agricultural irrigation, coupled with the possibility of bio-magnification up in the food-chain. The present article has made an attempt to take stock of this issue of considerable and long-standing environmental impact, as well as the appropriate mitigation options, involving people’s participation. The need for appropriate policy interventions has also been highlighted.

Keywords. Arsenic contamination; food-chain; health hazards; remedial measures.

1 Introduction

The word ‘Arsenic’ is borrowed from the Persian word زرنیخ Zarnik meaning ‘yellow orpiment’. Zarnik was borrowed by the Greeks as arsenikon. Arsenic has been known and used in Persia and elsewhere since ancient times. Also known as the Poison of Kings and the King of Poisons, arsenic was often included during the Bronze Age in bronze (mostly as an impurity), which made the alloy harder. Albertus Magnus is believed to have been the first to isolate the element in 1250 C.E. (Antman 2001). Arsenic has also been used as a pest killer. With pesticide sprays began the practice of contaminating human food and environment with arsenic, resulting in adverse effects on the health of many people and their offspring. Underground arsenic threatens drinking water resources in many parts of the world, and the consumption of the tainted water over the years must have resulted in the untold suffering of millions of people (Nriagu 2002).

Arsenic, a toxic trace metalloid, is of great environmental concern due to its presence in soil, water, plant, animal and human continuum. Its high toxicity and increased appearance in the biosphere have triggered public and political concern. Out of 20 countries (covering Argentina, Chile, Finland, Hungary, Mexico, Nepal, Taiwan, Bangladesh, India and others) in different parts of the world, where groundwater arsenic contamination and human suffering therefrom have been reported so far, the magnitude is considered to be the highest in Bangladesh, followed by West Bengal, India (Sanyal et al. 2015). The scale of the problem is grave and unprecedented, exposing millions of people in the Bengal delta basin to risk. The widespread arsenic contamination in groundwater in different parts of West Bengal, located primarily in five districts adjoining the river Bhagirathi, as well as the contiguous districts in Bangladesh, is of great concern. Beyond the Bengal delta basin, widespread arsenic contamination in groundwater above the permissible limit (50 μg As. L⁻¹; WHO 2001; see below) has also been detected in several places in the country (Table 1), for instance, at Chandigarh (1976), Bihar (2002), Uttar Pradesh (2003), Jharkhand (2003–2004), Chhattisgarh and Punjab (2006–2007) (Sanyal 2017). Further, Table 2 and Table 3 present the arsenic concentration in rocks and some
other materials as well as arsenic concentrations in water other than groundwater, respectively.

2 Guideline Value of Maximum Arsenic Concentration

The World Health Organization (WHO)-recommended provisional guideline value of total arsenic concentration in drinking water is 10 µg As. L\(^{-1}\) since 1993 (WHO 1993, WHO 1996), mainly because lower levels preferred for the protection of human health are not reliably measurable on a large scale. However, the National Standard for the maximum acceptable concentration (MAC) of arsenic in drinking water is 50 µg As. L\(^{-1}\) in several countries including India and Bangladesh, based on an earlier WHO (1971) advice. However, recently, the acceptable limit for drinking purpose in this country has been revised to the WHO-prescribed safe limit, namely 10 µg As. L\(^{-1}\). A proposed new standard value of 5 µg As. L\(^{-1}\) is under consideration. This is due mainly to the fact that inorganic arsenic compounds are classified in Group 1 (carcinogenic to humans) on the basis of adequate evidence for carcinogenicity in humans and limited evidence for carcinogenicity in animals (IARC 1987). Adequate data on the carcinogenicity of organic arsenic have not been generated. The joint FAO/WHO Expert Committee on Food Additives (JECFA) set a provisional maximum tolerable daily intake (PMTDI) of inorganic arsenic by humans as 2.1 µg As. kg body weight\(^{-1}\).day\(^{-1}\) in 1983 and confirmed a provisional tolerable weekly intake (PTWI) as 15 µg As. kg body weight\(^{-1}\) in 1988 (FAO/WHO 1989). Such guideline values for soil, plant and animal systems are not available.

Table 1 Groundwater arsenic contamination in the Indian subcontinent

<table>
<thead>
<tr>
<th>State</th>
<th>Coverage</th>
<th>Level of contamination in groundwater (µg As. L(^{-1}))</th>
<th>Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Bengal</td>
<td>12 Districts (Malda, Murshidabad, Nadia, North 24-Parganas, South 24-Parganas, Kolkata, Howrah, Hooghly, Barddhaman, North Dinajpur, South Dinajpur, Coochbehar), 111 blocks</td>
<td>50–3700</td>
<td><a href="http://www.soesju.org/arsenic/wb.htm">http://www.soesju.org/arsenic/wb.htm</a></td>
</tr>
<tr>
<td>State</td>
<td>Districts Description</td>
<td>Arsenic Concentration</td>
<td>Source</td>
</tr>
<tr>
<td>-------------</td>
<td>--------------------------------------------------------------------------------------</td>
<td>-----------------------</td>
<td>------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Jharkhand</td>
<td>1 District (Sahibgunj)</td>
<td>&gt; 50</td>
<td><a href="http://www.soesju.org./arsenic/jharkhand.htm">http://www.soesju.org./arsenic/jharkhand.htm</a></td>
</tr>
<tr>
<td>Uttar Pradesh</td>
<td>21 Districts (Ballia, Lakhimpur, Kheri, Baharaich, Chandauli, Gazipur, Gorakhpur, Basti, Siddharthnagar, Balarampur, Sant Kabir Nagar, Unnao, Bareilly, Moradabad, Rae Bareli, Mirzapur, Bijnore, Meerut, Sant Ravidas Nagar, Shahjahanpur and Gonda)</td>
<td>&gt; 50</td>
<td><a href="http://www.nerve.in/news:253500133730">http://www.nerve.in/news:253500133730</a></td>
</tr>
</tbody>
</table>
3 Arsenic Contamination in Groundwater in the Bengal Delta Basin

The groundwater arsenic concentration (50–3700 µg As. L⁻¹), reported from the affected areas of West Bengal, is several orders of magnitude higher than the stipulated Indian standard for the permissible limit in drinking water, as well as the WHO guideline value (10 µg As. L⁻¹). Further, the arsenic concentration in alluvial aquifers of Punjab varied from 4 to 688 µg. L⁻¹ (Sanyal et al. 2012). In West Bengal, the presence of arsenic in groundwater in concentrations exceeding the acceptable limit was first detected in 1978, while the first case of arsenic poisoning in humans was diagnosed at the School of Tropical Medicine in Calcutta in 1983 (Acharya 1997). The effect of ingestion of inorganic arsenic in drinking water and the associated health effects in adults have also been well-established by physicians (Guha Mazumder et al. 1998).

The main focus of attention, until recently, has been exclusively on arsenic concentration in groundwater-derived drinking water. However, since groundwater is also used extensively (to the tune of 85–90%) for crop irrigation in the arsenic belt of West Bengal, the possibility of a build-up of arsenic concentration in agricultural soils and agronomic produce was anticipated. Indeed, arsenic uptake by crop plants grown in soils contaminated with a high concentration of arsenic, and irrigated with such arsenic contaminated groundwater has been reported by several workers (reviewed by Sanyal et al. 2015; Sanyal 2017). Such findings call for immediate attention since what remains essentially a point and a fixed source of arsenic contamination for the drinking water (e.g. a tube well discharging contaminated water), may well become a diffuse and an uncertain source of contamination when arsenic finds its way into the food-web, accompanied with possible bio-magnification up in the food chain. This assumes added significance in view of the reported finding of a higher (than permissible) level of arsenic in the urine samples (an early biomarker of arsenic poisoning in humans) of some people, having no history of consuming arsenic-contaminated drinking water (Dr. D. N. Guha Mazumder, personal communication). Interestingly, the surface water bodies, located in the affected belt, have remained largely free of arsenic. This tends to suggest that the soil, which receives arsenic-contaminated water, acts as an effective sink to contain the toxin, thereby preventing the surface run-off to carry it to the adjoining water systems (Sanyal 2005).
Table 2 Arsenic (As) concentration in rocks and some other materials

<table>
<thead>
<tr>
<th>Types of rocks/materials</th>
<th>Arsenic content (mg As kg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Rocks</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Igneous rocks</strong></td>
<td></td>
</tr>
<tr>
<td><em>Ultrabasic</em></td>
<td></td>
</tr>
<tr>
<td>Peridotite, Dunite, Serpentine</td>
<td>0.3–15.8</td>
</tr>
<tr>
<td><em>Basic</em></td>
<td></td>
</tr>
<tr>
<td>Basalt (extrusive)</td>
<td>0.18–113</td>
</tr>
<tr>
<td>Gabbro (intrusive)</td>
<td>0.06–28</td>
</tr>
<tr>
<td><em>Intermediate</em></td>
<td></td>
</tr>
<tr>
<td>Latite, Andesite, Trachyte (extrusive)</td>
<td>0.09–13.4</td>
</tr>
<tr>
<td>Diorite, Granodiorite, Syenite (intrusive)</td>
<td>3.2–5.4</td>
</tr>
<tr>
<td><em>Acidic</em></td>
<td></td>
</tr>
<tr>
<td>Rhyolite (extrusive)</td>
<td>0.18–15</td>
</tr>
<tr>
<td>Granite (intrusive)</td>
<td></td>
</tr>
<tr>
<td><strong>Metamorphic rocks</strong></td>
<td></td>
</tr>
<tr>
<td>Quartzite</td>
<td>2.2–7.6</td>
</tr>
<tr>
<td>Slate/Phyllite</td>
<td>0.5–143</td>
</tr>
<tr>
<td>Schist/Gneiss</td>
<td>0.0–185</td>
</tr>
<tr>
<td><strong>Sedimentary rocks</strong></td>
<td></td>
</tr>
<tr>
<td><em>Marine</em></td>
<td></td>
</tr>
<tr>
<td>Shale/Claystone(near-shore)</td>
<td>4.0–25</td>
</tr>
<tr>
<td>Shale/Claystone(off-shore)</td>
<td>3.0–490</td>
</tr>
<tr>
<td>Carbonates</td>
<td>0.1–20.1</td>
</tr>
<tr>
<td>Phosphorites</td>
<td>0.4–188</td>
</tr>
<tr>
<td>Sandstone</td>
<td>0.6–9.0</td>
</tr>
<tr>
<td><em>Nonmarine</em></td>
<td></td>
</tr>
<tr>
<td>Shales</td>
<td>3.0–12</td>
</tr>
<tr>
<td>Claystone</td>
<td>3.0–10</td>
</tr>
<tr>
<td><strong>2. Coal</strong></td>
<td></td>
</tr>
<tr>
<td><strong>3. Crustal Average</strong></td>
<td>Up to 2000</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
</tr>
</tbody>
</table>
Table 3 Arsenic (As) concentrations in water other than groundwater

<table>
<thead>
<tr>
<th>Source</th>
<th>Arsenic concentration (µg As. L⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainwater and snow</td>
<td>&lt; 0.002–0.59</td>
</tr>
<tr>
<td>Rivers</td>
<td>0.20–264</td>
</tr>
<tr>
<td>Lakes</td>
<td>0.38–1.00</td>
</tr>
<tr>
<td>Sea water</td>
<td>0.15–6.00</td>
</tr>
<tr>
<td>Ponds (West Bengal, India)</td>
<td>4–70</td>
</tr>
<tr>
<td>Canals (West Bengal, India)</td>
<td>40–150</td>
</tr>
</tbody>
</table>

4 Health Implications of Arsenic Poisoning

Arsenic is a widely occurring toxic metalloid in natural ecosystems. As small as 0.1 g of arsenic trioxide can prove lethal to humans (Jarup 1992). Early symptoms of arsenic poisoning include skin disorders, weakness, languor, anorexia, nausea and vomiting with diarrhoea or constipation. With the progress of poisoning, the symptoms attain more characteristic features, which include acute diarrhoea, edema (especially of the eyelids and ankles), skin pigmentation, arsenical melanosis and hyperkeratosis, enlargement of the liver, respiratory diseases and skin cancer. Some of these symptoms are shown in Plate 1. In severe cases, gangrene in the limbs and malignant neoplasm are also observed (Guha Mazumder et al. 1998; Sanyal et al. 2012). The ‘Bell Ville Disease’ (typical arsenic-induced cutaneous manifestations among the people of Bell Ville) in Argentina, ‘Black Foot Disease’ in Taiwan and ‘Kai Dam’ disease in Thailand are well-established as health disorders due to arsenic poisoning (Sanyal et al. 2012). As a matter of fact, the hair, nail, skin-scale and urine samples of a large number of people, residing in the affected belt of West Bengal (India) and Bangladesh, have been analyzed by several workers. Many of these samples had more arsenic loading than permissible.
5 Arsenic Forms in Groundwater-Soil Environment and Toxicity

Arsenic in groundwater and soil is present as dissolved oxyanions, namely arsenites (trivalent arsenic) or arsenate (pentavalent arsenic), or both, besides the organic forms. The solubility, mobility, bioavailability and hence toxicity of arsenic in the soil-crop system primarily depends on its chemical form, mainly the oxidation state (valency) of arsenic, also on whether the arsenic is present in inorganic or organic combinations. The toxicity of arsenic compounds in groundwater/soil environment follows the order:

Arsine \([\text{AsH}_3; \text{valence state of arsenic: 3}]\) > organo-arsine compounds > arsenites and oxides (trivalent arsenic form) > arsenates (pentavalent arsenic form) > arsonium metals (monovalent arsenic form) > native arsenic metal.

The arsenites are much more soluble, mobile, and toxic than arsenates in aquatic and soil environments. The organic forms, namely dimethyl arsinic acid (DMA) or cacodylic acid, which on reduction (e.g. in anoxic soil conditions) forms volatile di- and trimethyl arsines, are also present in the soil. Another organic form present in groundwater and soil is monomethyl arsenic acid (MMA). The organic forms are much less toxic or non-toxic. Even though under
aerobic cultivation practices, the less toxic pentavalent arsenic forms are predominant; under submerged rice culture, the more soluble and toxic trivalent forms predominate.

6 Arsenic in Soil-Plant System and its Influence on Food-chain

It was noted that much more toxic trivalent arsenic accounted for the major arsenic species recovered from grains (edible) of the transplanted autumn paddy, while pentavalent arsenic predominates in rice straw (Sinha and Bhattacharyya 2014a; Sanyal et al. 2015). Further, the processing of rice (e.g., parboiling and milling, etc.) was found to increase the arsenic loading in rice for both the traditional and the high yielding cultivars (Sanyal et al. 2012). Soil amendment through organic manure reduced arsenic accumulation in rice grain and straw of autumn rice as revealed by the corresponding reduction of inorganic arsenic loading (Sinha and Bhattacharyya 2014b). Sinha and Bhattacharyya 2014b also studied the arsenic toxicity profile in rice, grown in the contaminated area of rural Bengal, and the possible risk of its dietary exposure. The risk of dietary exposure to inorganic arsenic through rice, the staple food in rural Bengal, has been noted to pose as great a threat to human health as the threat from contaminated drinking water. Organic amendments and augmented phosphate as well as selective micronutrient (e.g., zinc and/or iron salts wherever appropriate) fertilization showed considerable promise in reducing total and inorganic arsenic accumulation in rice and the consequent dietary risk (Mukhopadhyay et al. 2002; Sinha and Bhattacharyya 2011; Ghosh et al. 2012; Sanyal et al. 2015; Das et al. 2016).

Few reports are available that characterize the daily arsenic exposure through water and diet among the people living in groundwater contaminated regions and correlate the former with arsenic biomarkers. Demographic characteristics and the total daily arsenic intake through water and diet were determined in 167 participants (Group-1 participants, selected from the arsenic-endemic region) and 69 participants (Group-2 participants, selected from the arsenic-non-endemic region) in a study conducted in West Bengal by physicians working alongside agricultural scientists in a consortium mode. The findings showed significantly high dietary arsenic intake in people living in Nadia district of West Bengal, where contaminated groundwater was used for irrigation purpose, but significantly low in the region of Hooghly district, where groundwater was uncontaminated. Even after lowering the arsenic level in drinking water to < 50 μg As. L⁻¹ (the permissible limit in India), significant arsenic exposure occurred through water and diet, reflected by the elevated level of arsenic in the arsenic biomarker, namely urine, in people living in the arsenic-endemic region studied. Those with skin lesions were found to have a higher level of arsenic in urine and hair, compared to those without skin lesion (Guha Mazumder et al. 2013, Guha Mazumder et al. 2014). In yet another study, the dose of daily arsenic intake from both water and diet was found to be significantly and positively associated with urinary arsenic levels in an arsenic-endemic region of West Bengal, even when people were using arsenic-safe water (< 50 μg As. L⁻¹) for drinking and cooking purposes. When arsenic levels in drinking water were further reduced to < 10 μg As. L⁻¹ (WHO safe limit), the dose from the diet was still found to be significantly associated with
arsenic toxicity. But no significant association was found with arsenic dose from drinking water in this group (Halder et al. 2012; Guha Mazumder et al. 2013; Sanyal 2017). Further, when exposed to arsenic only through diet, the urinary arsenic concentration was found to correlate positively with dietary arsenic intake in the participants, showing skin lesions, while this correlation was insignificant in participants without skin lesion. Thus these facts, taken together, amply demonstrate that supply of arsenic-safe drinking water (< 10 μg As. L⁻¹) to the population in rural Bengal alone is not enough to reduce the risk of arsenic poisoning. Consumption of rice provides yet another potential pathway to inorganic arsenic (i-As) exposure, which must also be considered as a remedial option. Thus, any mitigating intervention to address chronic arsenic toxicity requires an integrated approach. The essential components should include attempts to bring down arsenic entry into the food-chain, and to reduce arsenic loading in drinking water to below safe limits. (Halder et al. 2012; Guha Mazumder et al. 2014; Sanyal et al. 2015; Golui et al. 2017; Sanyal 2017).

7 Remedial Options at a Glance

A number of remedial measures have been noted to be quite effective in reducing the arsenic loading in the economic produce of several crops including rice. Some of these have been mentioned earlier. The more effective ones are summarized below:

- Optimum conjunctive use of ground and surface water (e.g. harvested rainwater), to reduce contaminated groundwater for irrigation during the lean period, and recharge of groundwater resource with harvested rainwater, free of arsenic.
- Develop/identify low arsenic-accumulating, less water-intensive high yielding crop varieties and cropping sequences suitable for arsenic-contaminated areas, especially for the lean period of January to May (e.g. cropping sequences, Elephant foot yam-mustard-sesame, Green gram-rice-mustard, etc., instead of, for instance, Olitorius jute-rice-rice and Green manure-rice-rice).
- Irrigate with pond-stored groundwater in which partial decontamination is facilitated by sedimentation-cum-dilution with rainwater.
- Enhancing the water use efficiency (through optimum water management) for groundwater irrigation, especially for summer (boro) paddy (e.g. by having recourse to judicious intermittent ponding of summer paddy during the vegetative growth period, followed by continuous ponding during the subsequent reproductive phase, which does not affect the yield significantly while cutting down the contaminated groundwater use considerably).
- Increased use of FYM and other organic manures + green manure crops, as well as the application of appropriate inorganic amendments (zinc/iron salts as and wherever applicable).
- Identification/development of varieties/crops which accumulate less arsenic in the consumable parts, and where the ratio of inorganic to organic forms of arsenic is low.
- Developing cost-effective phyto- and bio-remediation options.
- Creation of general awareness through mass campaigning, holding of farmers’ day, field demonstrations, taking due cognizance of the socioeconomic factors.
- People’s participatory approach in the creation of mass-awareness about the menace as well as adopting and popularizing the remedial measures to address the problem at the local level (Mukhopadhyay and Sanyal 2004; Sanyal 2005; Sinha and Bhattacharyya 2011, Sinha and Bhattacharyya 2014a, Sinha...
8 Policy Interventions

The issue of arsenic contamination in groundwater in parts of the country and its adverse effect on human health has been agitating scientists, physicians, community workers, lawmakers and the general public at large, especially those who are suffering from its toxic effect. The primary attention, however, is directed towards solving the problem of such contaminated resource-based drinking water supplies to mostly the rural population. This is mentioned at the beginning of this article but is reiterated here to emphasize that the issue of addressing the drinking water sector itself is a huge challenge. The options have been mostly confined to the use of the relatively safe surface water, adequately clarified of its pathogen load, or tap the relatively deep aquifer layer (at a depth more than 150–200 m below the ground level) which is essentially free of the toxin in the affected belt. Periodic monitoring of the quality of such drinking water sources is also ensured quite satisfactorily.

However, what remains to be addressed is the food-chain issue which gets contaminated due to the entry of arsenic in it through the contaminated groundwater sources being pressed to irrigate the agricultural crops. This is not to undermine the existence of quite a vast amount of experimental data already generated by not only the agricultural scientists, but also the geologists, hydrogeologists, environmental experts and, most of all, the medical professionals (the latter till date in a moderate scale though) working in a consortium mode. It is quite reasonably well-established now that the food-chain contamination provides yet another potential pathway of arsenic exposure of the population in rural areas. Hence it is imperative that any comprehensive mitigating intervention of chronic arsenic toxicity in people requires integrated approaches toward reducing arsenic entry into the food chain, on one hand, while reducing arsenic in the drinking water below the safe limits, on the other. Unless this is attempted and accomplished, the food bio-safety concern, in its totality, is unlikely to go hand-in-hand with the food and nutritional security concerns of the country, not only for the domestic population but also for the export market. It appears that despite such realization at the level of scientists, it is yet to translate itself in terms of a concrete action plan, perhaps as a pilot programme initially, and finally as a large-scale initiative, to be implemented covering the entire affected belt. To ensure the latter, the concerned planners and the policymakers need to be adequately sensitized.

The success of such an integrated approach would essentially depend on its multi-level stakeholder nature, involving researchers, technologists as well as the planners with a focus on the real beneficiaries. The beneficiaries ought to be empowered through awareness and training to understand and participate actively in such mitigation programmes. A major shift from a purely technical to a holistic approach is needed to ensure a technically feasible, socially acceptable, economically viable and environmentally sound action plan.
9 Conclusions

Generating awareness and motivating people to test the quality of their drinking water for arsenic remains a key factor to contain the exposure to arsenic. In view of the unprecedented health hazard and misery among the affected people with severe skin lesion, the supply of arsenic-free drinking water, coupled with the arrangement of free treatment of these patients in the state referral hospital, could help considerably in alleviating the disease prevalence. This is all the more important keeping in view that the majority of the affected people are very poor and live in remote villages.

As stated earlier, arsenic-contaminated groundwater has been the main source of irrigation, drinking and allied activities in the affected areas of rural Bengal and elsewhere. Excessive use of arsenic contaminated groundwater resulted in an elevated level of arsenic in soil and food-chain. Thus, it is indeed high time that appropriate mass awareness is generated among the farming communities towards the judicious use of groundwater, coupled with appropriate remedial options discussed above to minimize the hazards of the toxin affecting the human food-web. Also, an integrated approach should bring together not only the agricultural scientists but also the physicians, social scientists as well as the planners at the local level.

The immediate needs, among others, include improvements of the field and the laboratory protocols for large-scale measurement of arsenic, as well as different forms/species of arsenic in groundwater-soil-plant-animal-human continuum. The latter is essential to characterize the net toxicity due to the entry of arsenic in the food-chain. Furthermore, strengthening of inter-institutional and inter-disciplinary action programme, long-term technical alternatives to reduce the dependence on arsenic contaminated resources is also the need of the day.

References


**Source**

1. Table 1: Sanyal 2017
2. Table 2: Sanyal 2017
3. Table 3: Sanyal 2017
India’s Nuclear Energy Program

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1 Abstract

I describe the development of nuclear energy in India, its current status and its future prospects vis-à-vis the global trends in the nuclear industry that are also summarized. A short discussion on carbon emissions and global warming is provided to assess the contribution that nuclear energy can make in mitigating the issue of climate change. The progress in India’s nuclear program prior to and in the aftermath of the Indo-US Nuclear deal is compared. The impact of the Nuclear Liability Act of 2010 on the expansion of our nuclear capacity is analysed. Finally, the public concern over radioactive hazards of nuclear energy is addressed. The genuine uncertainties in obtaining a reliable estimate of the damage done by a reactor explosion are pointed out, which make it difficult even for the intelligentsia to assess, on its own, the true extent of the danger. This underlines the importance of government agencies and NGOs dealing with this area retaining their credibility with the public.

Keywords: Carbon emissions; Indo-US Deal; Liability Act; nuclear energy; radiation hazards; spent fuel

2 Introduction

The subject of nuclear energy, despite its highly technical underpinnings, has generated wide public interest and some controversy over the past few decades, both globally and in our own country. On the one hand, the widely reported accidents at the reactor complex at Fukushima in Japan, and the earlier ones at Chernobyl in the erstwhile USSR and the Three Mile Island in
the US, have led to increased concerns about the safety of nuclear energy. Protests based on these concerns have erupted in many countries, with the Green Parties leading the charge in Western Europe. In India too, protests have accompanied the installation of nuclear reactors in places like Kaiga in Karnataka and more recently at Kudankulam in Tamilnadu. On the other hand, the fact that nuclear power is largely free of carbon emissions makes it an attractive form of energy production, given the alarming prospect of global warming and climate change. The latter are caused by the accumulation of carbon dioxide produced during conventional forms of energy generation using coal and hydrocarbons as fuel. Many environmental groups, which had opposed nuclear energy in the past, have had second thoughts about it in view of its possible role in mitigating global warming.

In India, reconciling these competing pros and cons of nuclear energy becomes all the more important because of our need to generate a large amount of energy to support a healthy rate of growth of the nation’s economy. The government has to decide how much emphasis it must place on accelerating its development of nuclear energy, along with the other traditional methods of producing electricity using coal, oil, gas and hydro-power as well as exploiting renewable sources like solar and wind energy. Furthermore, at the Paris Conference on Climate Change India has committed itself to a reduction in C emissions and, to implement that, has announced plans to increase nuclear energy capacity from about 7 GW (gigawatts) currently to as much as 63 gigawatts by 2032 (Grover 2017). Whether such an ambitious nuclear target can be reached in the face of several obstacles - the steeply rising costs of reactors, problems of land acquisition, public concerns over radioactive hazards, eventual disposal of nuclear waste etc. - remains to be seen.

In this article, I summarize the status and prospects of the development of India’s nuclear energy program and in the process, discuss all the above issues. I will also attempt to address the concerns of the public over the radiological hazards of nuclear energy.

3 Nuclear Energy: The Global Scene

In discussing how the Indian program has performed so far and how it is likely to evolve, it will be useful to do so in the context of the global status and history of nuclear energy. Accordingly, I will begin the discussion with a very brief history of nuclear energy around the world, where it has undergone a roller coaster ride ever since it was introduced 75 years ago. It has enjoyed periods of growth and optimism alternating with intervals when further prospects looked very gloomy. In the background of the worldwide trends, I will then discuss India’s nuclear energy program.

When the nuclear era dawned, atomic (nuclear) energy seemed to be the ultimate solution to mankind’s energy needs. The US started building nuclear reactors rapidly. Europe and the Soviet Union followed suit. India too started its nuclear program already in the late ’Forties’. Other developing countries were also encouraged to go nuclear by Eisenhower’s Atoms for Peace program. Thus, in the initial years, nuclear energy seemed to be living up to its promise
despite the fact that it involved a completely new area of technology. The dozens of reactors built in the US as well as in Russia and Europe functioned well and generated electricity.

But a few decades later, scepticism and opposition began to gather against nuclear energy in many countries. There was a variety of contributing factors to this:

(i) Major reactor accidents like the 3-mile Island accident in the US (1979) and the reactor blow-up at Chernobyl (1986) in the USSR. (The explosion at Fukushima was to come later!)

(ii) Greater safety and environmental consciousness around the world and the emergence of Green Parties in Europe

(iii) Growing awareness of the complexity and expense of Reactor Decommissioning and spent fuel disposal

Although some countries like France, Russia, China and India continued with their programs, the biggest producer, the US, stopped licensing of new reactors. After building 100 reactors by the 1970s, further growth was frozen for several decades in the US! Germany also stopped increasing nuclear capacity. In fact, some industrially advanced nations like Norway and Italy (which produced Fermi, the Father of nuclear reactors) have no nuclear power reactors.

Fig 1 shows the levelling-off of nuclear capacity in the world by 1990. In fact, plans to construct new reactors had stopped much earlier, but it gets reflected in the Table only 5–10 years later, after those reactors whose construction had already been started got completed and commissioned.
With the coming of the new Millennium, there were hopes of a revival in the fortunes of nuclear power. They were prompted by:

(i) Concern over climate change due to high carbon emission by coal and hydrocarbon-based fuels. To some environmental activists, nuclear energy with a relatively small Carbon footprint began to seem a lesser evil than global warming.

(ii) Improved reactor safety features and passage of two more decades of reactor use with no major accidents – making them ‘statistically’ safer.
4 How Much Nuclear Energy Would the Climate Change Mitigation Call for?

The field of climate change has generated a vast amount of literature during the past two decades, both on its scientific aspects as well as on its political and economic ramifications. Large and learned tomes have been written on the subject and it would be futile to attempt to summarize them in this article, whose primary theme is nuclear energy. I will, therefore, be content to take as given that excessive carbon emission and the resultant global warming are potentially very serious dangers. I will just show a couple of key graphs on the extent of carbon emission and possible ways to reduce it in the future.

I will use a pioneering piece of work by Pacala and Socolow which gave a simple and tractable encapsulation of this complex subject and discussed ways to mitigate further C emission through a variety of measures, including nuclear energy (Pacala and Socolow 2004). Fig. 2 below, taken from their work, shows the measured growth of annual C emission over the years. From 1954 to 2004, when their work was published, the measured annual carbon emission data follows, apart from some smaller wiggles, roughly a straight line as shown in Fig. 2.
In 2004, as the graph shows, the annual C emission was already about 7 gigatons. This level of emission, if continued year after year, would already be considered unsafe from the climate change point of view. But if the emission rate itself continued to increase as it has in the past (i.e. if the world continued on a ‘business as usual’ path) then we have the emission trajectory going up to 14 gigatons by 2054, which, as per all reasonable estimates by most experts, would be truly disastrous.

Given this, Socolow argues as follows. Suppose we consider even the modest goal of keeping the emission rate at the 2004 level, i.e. at about 7 gigatons of carbon per year that would already be a hard thing to achieve. To appreciate this, note that the total quantity of carbon emitted is (with appropriate units on the x and y-axis of the graph) the area under the rate curve of Fig 2. Therefore, if we wish to maintain the annual rate of C emission at the 2004 level of 7 gigatons, we have to either live without, (or replace by some other source) the energy that would have been produced by the amount of carbon in the triangular area shown in green.

To get some tentative idea of possible ways to deal with the loss of that much carbon-based energy, Socolow divides the green triangle (he calls it the Stabilization Triangle) into 7 equal portions, each a triangular wedge as I have shown in the figure. Each wedge represents carbon emissions whose annual rate would grow from zero to 1.0 gigatons of carbon (GtC)/yr. over
the course of 50 years. He then considers different measures to replace the loss of each wedge’s worth of coal-based energy. Some examples are shown in Fig 3.

![Fill the Stabilization Triangle with Seven Wedges](image)

Fig 3 Possible ways of compensating for the loss of hydrocarbon-based energy production.

Assuming that nuclear fission is assigned, along with the other measures in Fig 3, the responsibility for replacing one of the ‘wedges’, Socolow estimated that this would correspond to building another 700 GWe of additional nuclear energy capacity globally by the year 2050. This would be in addition to the roughly 400 GWe the world already has. [Nuclear fusion on a commercial scale is too far away to provide much solace right now.]

Note that the Pacala-Socolow analysis was published in 2004, using the C emission graph till that time, as shown in Fig 2. Subsequently, the rate of Carbon emission has grown even steeper. Fig 4 contains the annual emission data up to 2014, which shows a more rapid rate of emissions since 2004. This makes the burden on nuclear energy for replacing 1/7th of the total fossil fuel energy even higher, well over 1000 GWe.
One can ask if the world has enough uranium ore under the ground to support over a thousand reactors, each of 1 gigawatt power. Fig. 5, prepared under the aegis of IAEA (the International Atomic Energy Agency), gives the availability of global uranium resources, with estimates of how long it will last. This is calculated both using conventional ‘once through’ technology and using closed cycle technology with fast reactors. The entries in the Table are self-explanatory and the short answer is that there are plenty of uranium resources to fuel 1000 Gigawatts nuclear energy for a century.
So, with climate change compulsions thus providing a new impetus for building more reactors, and sufficient availability of uranium ore underground to support them, things began to look rosy again for nuclear energy in the new Millennium. But, then came Fukushima! Thanks to massive television coverage around the world, the Fukushima reactor explosions in March 2011 had a massive impact (more than the larger disaster at Chernobyl) on public perceptions of nuclear energy. The nuclear industry, hoping to enjoy a ‘renaissance’ had instead to face charges of being unsafe and expensive. Anti-nuclear activists worldwide felt freshly empowered and demanded closure of nuclear reactors.

Different countries responded differently to Fukushima. Germany decided to phase out its entire nuclear program in a decade. The US, the UK, Russia and China conducted safety reviews to the extent they saw fit and decided to continue with their nuclear energy plans, but in a more cautious manner. UAE has gone ahead with plans to build 4 reactors in an $18 billion deal with South Korea. What about India? That brings us to our own nuclear program.
5 India’s Nuclear Energy Program

In the background of this global history, let us discuss the Indian program. Thanks to the pioneering vision of Dr. Homi Bhabha and the support he got from Pandit Nehru, our nuclear program had formally begun already in the late forties, before most nations. Since then DAE (The Department of Atomic Energy) has been enjoying strong support from the Government. It grew steadily but slowly. In more than 5 decades, by the end of Millennium, they had only been able to develop a capacity of less than 3 GWe. The list of power reactors in DAE’s stable by the year 2000 is given in Table 1 (The current list will be shown in Fig 6).

Table 1  List of power reactors operating in India at the turn of the century

<table>
<thead>
<tr>
<th>Power reactor</th>
<th>Date of commencement</th>
<th>Type</th>
<th>Power (MWe)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaiga-1</td>
<td>16-Nov-00</td>
<td>PHWR</td>
<td>220</td>
</tr>
<tr>
<td>Kaiga-2</td>
<td>16-Mar-00</td>
<td>PHWR</td>
<td>220</td>
</tr>
<tr>
<td>Kakrapar-1</td>
<td>6-May-93</td>
<td>PHWR</td>
<td>220</td>
</tr>
<tr>
<td>Kakrapar-2</td>
<td>1-Sep-95</td>
<td>PHWR</td>
<td>220</td>
</tr>
<tr>
<td>Madras-1</td>
<td>27-Jan-84</td>
<td>PHWR</td>
<td>170</td>
</tr>
<tr>
<td>Madras-2</td>
<td>21-Mar-86</td>
<td>PHWR</td>
<td>220</td>
</tr>
<tr>
<td>Narora-1</td>
<td>1-Jan-91</td>
<td>PHWR</td>
<td>220</td>
</tr>
<tr>
<td>Narora-2</td>
<td>1-Jul-92</td>
<td>PHWR</td>
<td>220</td>
</tr>
<tr>
<td>Rajasthan-1</td>
<td>16-Dec-73</td>
<td>PHWR</td>
<td>100</td>
</tr>
<tr>
<td>Rajasthan-2</td>
<td>1-Apr-81</td>
<td>PHWR</td>
<td>200</td>
</tr>
<tr>
<td>Rajasthan-3</td>
<td>1-Jun-00</td>
<td>PHWR</td>
<td>220</td>
</tr>
<tr>
<td>Rajasthan-4</td>
<td>23-Dec-00</td>
<td>PHWR</td>
<td>220</td>
</tr>
<tr>
<td>Tarapur-1</td>
<td>28-Oct-69</td>
<td>BWR</td>
<td>160</td>
</tr>
<tr>
<td>Tarapur-2</td>
<td>28-Oct-69</td>
<td>BWR</td>
<td>160</td>
</tr>
</tbody>
</table>

6 Why was the Development so Slow?

One major factor was the unavailability of funds. Till the 1990s, India was a ‘poor and developing’ country. (Of course, in many ways, it still is, but that is a different story!). Another

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factor was the imposition of international sanctions after India’s nuclear test in 1974. No nuclear technology or materials could be bought from outside. On top of all these handicaps, our uranium ore turns out to be limited in quantity and quality. According to the IAEA ‘Redbook’ we have only 158,000 tons–129,012 tons of U as Reasonably Assured Resources and 29,270 tons of U as Inferred Resources. Our rate of mining is only 300 tons a year. Even some existing reactors had to be run at low capacity factors because of fuel shortage.

Some people also feel, rightly or wrongly, that there was too much awe of DAE and insufficient pressure on them to push harder. If true, this may have been the flipside of the enormous support DAE has enjoyed, thanks to Bhabha, Nehru and the Bombs.

Be that as it may, notwithstanding the relatively slow rate of development in India’s nuclear program in its first fifty years, the new millennium saw a decisive push for faster and more substantial increase in our nuclear capacity. By 2010, ten more indigenous reactors were completed and commissioned at Kaiga, Tarapur and Rajasthan. The government had also brought out a new Integrated Energy Policy document outlining the energy required to enable an 8% Growth in GDP (Planning Commission 2006). Table 2.7 of that document sets the targets for energy production from different sources during the next 2–3 decades. Excerpts from these targets are summarized in Table 2 below:

Table 2 Targets for different energy sectors taken from the Integrated Energy Policy of 2006, Government of India.

<table>
<thead>
<tr>
<th>Year</th>
<th>Total GWe</th>
<th>Thermal GWe</th>
<th>Hydro GWe</th>
<th>Nuclear GWe</th>
<th>Renew</th>
</tr>
</thead>
<tbody>
<tr>
<td>2021-22</td>
<td>301</td>
<td>231</td>
<td>41</td>
<td>26.1</td>
<td>2.7</td>
</tr>
<tr>
<td>2031-32</td>
<td>551</td>
<td>430</td>
<td>61</td>
<td>57</td>
<td>3.6</td>
</tr>
</tbody>
</table>

One can see that this plan calls for generating 26.1 GWe of nuclear energy by the year 2022 and 31 more gigawatts in the ten years after that. These are obviously very ambitious targets considering that at the time of the preparing the Planning Commission Report, we had less than 4 GWe of nuclear power altogether.

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7 Indian Commitments at Paris

India committed to reducing greenhouse gas emissions intensity - i.e. the ratio between a country’s gross emissions to its gross domestic product - by 33–35 per cent by 2030, compared to 2005 levels. For this, India has to ensure that about 40% of its electricity henceforth comes from non-fossil fuel. Currently, it is around 30%. Towards this goal, India plans to increase its nuclear capacity to 63 GW by 2032 (Grover 2017) by building roughly 60 reactors, which would make it the world’s second-biggest nuclear energy market after China. Can India achieve the desired nuclear target of 63 Gwe by 2032? Certainly, it could not have, without the much-maligned Indo-US Nuclear Deal and the Nuclear Suppliers Group lifting international sanctions (in 2008). For one thing, it does not have the capacity now to suddenly build 50 more reactors within two decades, after having been able to build only about 20 power reactors in over 60 years since the inception of DAE. For another, we do not have enough indigenous uranium to fuel so many reactors. [We do have large deposits of thorium. It is in principle possible to use that thorium for fuelling reactors after first transmuting it to Uranium 233. This possibility in the Indian context was suggested by Bhabha. Scientifically, it is a very good idea but there are fairly difficult intermediate steps which make it difficult to achieve in the short term. [To avoid a digression, I discuss this issue separately in the box below.]

But thanks to the Indo-US Nuclear Deal, we are now allowed to

(i) import uranium, and

(ii) enter into collaboration with other countries on building reactors.

After 3 years of hard negotiations, the Indo-US Nuclear Deal was concluded in 2008 and the nuclear sanctions against India were lifted by the Nuclear Suppliers Group Countries (Rajaraman 2009). Let us look at the extent to which we have so far been able to take advantage of the new freedom on nuclear commerce.

\[2\] 21st Conference of the Parties, or COP2, to the UN Framework Convention on Climate Change (UNFCCC), held in Paris, 30 November to 11 December 2015
The Thorium factor

Although we are short of Uranium ore, we do have large deposits of Thorium. It has been repeatedly suggested that we use our Thorium for fueling reactors. In this box we briefly address the Thorium possibility. Thorium is NOT a fissile material, i.e., it cannot undergo nuclear fission. But it can be converted, when placed in a ‘Fast Breeder’ reactor, into U(233) which is fissile. The U -233 deposited in the spent fuel can be extracted in ‘re-processing units’ and used as an input fuel, closing the ‘fuel cycle.’ This is the Bhabha Plan. In principle, it is a good plan. But on a commercial scale, such Breeder technology is nowhere nearly as sturdy as conventional reactors. Among a total of 443 commercial reactors in the world, there are only a couple of functioning breeders: The US and Germany long ago gave up on commercial Breeders. France and Japan had only one each (the Phoenix and the MONJU respectively). Both had major coolant (liquid Sodium) problems and have been abandoned. China has put its Breeder plans on the backburner. Only Russia has a couple of Breeders. India’s first commercial Breeder is still under construction at Kalpakkam. Our DAE scientists claim that they have devised, despite their isolation, new techniques to manage the sodium safely. It was supposed to be ready in 2010 but is still not, 7 years later. We have a long and challenging task ahead (at least 20 more years) to achieve commercially viable energy using Thorium. Meanwhile, we have to rely on Uranium for fuel.

8 Progress after the Nuclear Deal

On uranium purchase, the Government has moved fast and organized the purchase of Uranium from several countries. Agreements were made to enable purchases of Uranium from Kazakhstan, Namibia, Mongolia, Niger, Canada, and recently Australia. Till now, about 5,559 MT (metric tonnes) of Uranium has come into the country from the Russian Federation, Canada and Kazakhstan, alongside France, while 2,937 MT is the anticipated supplies of natural uranium ore concentrate and natural uranium oxide pellets.

On importing reactors, i.e. on arranging for reactor builders from other countries to construct reactors in India, progress has been hindered by several factors. This is unfortunate because it is a crucial element in our plans for nuclear expansion. On its own, the DAE has been able to build reactors only slowly and even those were limited to only one type of reactors, the PHWRs (Pressurised Heavy Water Reactors) of relatively small capacity. To their credit, the DAE scientists have been able to upgrade and operate larger versions of that reactor, starting from the earlier ones of 220 MWe each to bigger ones of 500 MWe and now 700 MWe capacity.
But to have a substantial up to date nuclear capacity, one needs to have a fleet of modern Light Water Reactors in the range of 1000 MWe and higher.

Note that even though the US under President Bush exerted itself considerably on India’s behalf and did all the heavy lifting to persuade other countries to remove the nuclear sanctions against India, there was no requirement in the Indo-US Deal that India must buy any US-built reactors. In fact, once the Deal was done, Russia and France, which were waiting for the sanctions to be lifted, also signed, along with the US, initial agreements for construction of reactors in India.

NPCIL quickly entered into preliminary agreements and MOUs with Westinghouse on the construction of AP1000 Pressurized Water Reactors (PWRs), and with GE Hitachi for the construction of Advanced Boiling Water Reactors of the capacity of 1350 MWe each. These US reactors were to be built at Mithi Virdi in Saurashtra, and Kovada in Andhra Pradesh.

Meanwhile, the French reactor building giant AREVA was allotted a reactor park at Jaitapur in Maharashtra. They are expected to build six EPR (European Pressurized Reactor) units with a capacity of 1650 MWe apiece.

The Russians were offered a ‘reactor park’ to be located at Haripur in West Bengal to house eight 1000 MWe VVER reactors. But that venue had to be shied because of objections from the West Bengal government. But the Russians had already started building two reactors for us at Kudankulam even before the international sanctions were lifted. The sanctions were bypassed using what is known in the trade as ‘grandfathering’, i.e. claiming that the agreement to build them had preceded the imposition of sanctions. Other countries tacitly looked the other way (this seems to happen often in the international community). In fact, the Chinese are building two reactors near Karachi using the same argument!

However, progress in bringing the agreements with all these three countries to fruition ran into a roadblock because of India’s newly enacted Nuclear Liability Act passed in 2010. The Act had several progressive measures including (i) a Reactor-operator liability of $300 million and (ii) a requirement that a claim for compensation by a victim will have to be dispatched by a special court within 3 months of application and the award accordingly made. Compare this with the experience of victims of the Bhopal Gas Leak tragedy!

But the Liability Act also contained a clause permitting the Operator to sue the reactor Suppliers in the event of an accident or malfunction. On the surface, such supplier liability may sound reasonable. If a car accident took place, not only are the owner and driver liable but also the manufacturer, if faulty car parts were proved to be responsible. Nevertheless, in the nuclear reactor commerce, such a liability clause went against international practice. No other reactor buyer country includes such a condition.

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Not unexpectedly, all the suppliers from the US, France and Russia were unhappy with the supplier liability clause. There was also concern that no insurance companies would be willing to cover the risk on behalf of the suppliers. The government tried out many ideas to assuage the concerns of the foreign suppliers, but reactor builders were not persuaded. Further agreements came to a grinding halt with no forward motion between 2010 to 2013.

Eventually, a mutually acceptable solution was found through the formation of an Insurance Pool. The Liability of Rs. 15 billion in the event of an accident would be split between GIC (The General Insurance Corporation of India) and four other insurance firms and the Government would provide more at a later date ‘on a tapering basis.’ The additional insurance costs for the suppliers would be partly absorbed into the purchase price in the agreements.

Things began to move again.

9 Russian Built Reactors

Since then, the most progress has been on Russian reactors. As mentioned earlier, the Russian nuclear giant ROSATOM had already been building two reactors for us at Kudankulam after bypassing the nuclear sanctions on the argument of ‘grandfathering.’ After the sanctions were lifted, the Russians agreed last year to build two more 1000 MWe reactors (units 3&4 at Kudankulam) for $2.5 billion each, which will generate electricity at Rs. 6 a unit. The price was adjusted to include nuclear liability costs. Of these, Unit 3 is scheduled to be completed in March 2023 and unit 4 the subsequent year.

India and Russia have also signed an agreement for another two reactors (5&6) at Kudankulam. The entire project will cost about $ 7-8 billion. The first unit will be commissioned in 66 months and the second six months thereafter. The Russian collaboration is the only one going full steam at the time of writing.

By comparison, things look dismal on the Western Front. After the liability concerns were resolved, it was announced during Mr. Modi’s Washington visit in June 2016 that NPCIL and Westinghouse will immediately start engineering and site design work. The six Westinghouse AP-1000 reactors would be built in Andhra Pradesh after the original site in Gujarat faced local opposition. NPCIL reportedly made a down payment on 2,000 acres (800 hectares) of land in the coastal district of Srikakulam.

However, even though new agreements were made with the US and French companies, their prospects are very bleak now. Both the reactors firms seem quite dysfunctional now with serious the financial solvency problems. Westinghouse has announced bankruptcy. Its parent company Toshiba, does not want to bail it out. It is not clear how they can build the 6 reactors

[4] In May 2018 I had the opportunity to visit Rosatom’s massive Atomenergomash plant at Volgodonsk near the river Don in Russia where we were shown the components for the Kudankulam reactors III and IV being actually assembled.
India’s Nuclear Energy Program

for India. Moreover, GE has announced that it would not enter into a similar arrangement because of continuing liability concerns. There has been a very recent development with regard to Westinghouse. The Canadian company Brookfield has agreed to buy out Westinghouse. Since Canada is involved, it is unclear whether the construction deals will need a new nuclear agreement with Canada. It remains to be seen how this will proceed further.

Prospects of the French collaboration also look gloomy. Areva has reportedly agreed to a price of Rs.6/kWh – up from the earlier Rs. 3–4/kWh with some ‘Make in India’ collaboration with the Indian company Larsen and Toubro. But Areva is also broke. In late 2014, Areva suspended its financial outlook statement due to cash flow problems. Soon thereafter Standard and Poor lowered its credit rating to BB (junk status). The French government has been on a re-organization and rescue operation for Areva. Besides, Areva has had a terrible record in constructing their EPR reactors – the same model that they wish to sell us. Their EPR reactor in Olkiluoto, Finland, started in 2005, is still not ready. Meanwhile, the cost has gone up from €3.7 Million to over € 8.5 billion. Even within France, another EPR reactor at Flamanville started in 2007, is not ready yet. Its cost too has shot up from €3.3 billion to €8.5 billion. However, similar EPRs are being constructed by Areva in Taishan, China at reportedly €4 billion each and suffering fewer delays. We should carefully monitor their progress.

All in all, the program to import reactors from the US and France is proceeding forward slowly and is well behind schedule. Perhaps in part because of this, India has announced a program of building 10 new indigenous reactors. Presumably, this is in response to the problems with both the France and US reactor projects. These would all be CANDU reactors of 700 MWE each.

At the time of writing, all these are still plans and the current set of functioning power reactors is given in Table 1. Their collective installed capacity is 6.78 GWe, including a significant fraction of 2 GWe coming from the Russian built reactors at Kudankulam. Altogether that represents less than 3% of our current electricity requirements.

Readers are also encouraged to look at the DAE perspectives on these developments. There are several excellent articles by Dr. R. B. Grover, a member of India’s Atomic Energy Commission for several years, on our nuclear program. His review published last year is a good example (Grover 2017).
Disposal of Spent Fuel from Reactors

In the early years of nuclear energy, there was not much concern, except among experts, about what would happen to the contents of a reactor after use. These contents would be, in the first instance, its spent fuel rods as they get used up are removed and replaced, and eventually of the whole reactor itself after it completes its usable life. The focus in the initial years was on designing, building and running the reactors successfully to generate power. But as the decades rolled by, the reactors began to age and their spent fuel rods started accumulating. Gradually public consciousness began to get raised on the importance and cost of dealing with the highly radioactive content of used reactors and their fuel.

Let me briefly explain what the spent fuel disposal problem is. A typical power reactor’s fuel consists of uranium, which is primarily made of the isotope U-238 which is NOT fissile and smaller amount of U-235 which is its source of fission energy. (Some reactors have mixed fuel containing plutonium as well, but most of what we say in this introductory discussion applies to them too.) The fraction of U-235 in the fuel depends on its ‘enrichment’ level. ‘Natural’ Uranium extracted from Uranium ore has about 0.7% of U-235. Such natural Uranium is what is used in the Heavy-Water Moderated CANDU reactors – the workhorse of the Indian reactor
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stable. Most reactors in the world are Light-Water Reactors, which need Uranium that has to be enriched to 3–4.5% of U-235, generally done in gas centrifuges.

This Uranium is machined into ‘fuel rods’ which are bundled together to form the fuel assembly placed at the reactor’s core. As the reactor burns its fuel its U-235 content keeps getting diminished until it reaches a level that is no longer sufficient to generate the required rate of fissions to keep the reactor running. At that stage, these ‘spent’ fuel rods are removed and replaced by new ones. The spent fuel rods contain various highly radioactive elements - not just the original Uranium isotopes but other nuclei, produced by the impact of neutrons generated in the reactor, plus their subsequent decay products. The problem of disposal of fuel rods is to find ways of storing them away safely so that their radioactive emissions do not harm people and the environment.

The storage of spent fuel is still a ‘work in progress’ in many countries which have not determined the ultimate fate of their spent fuel. The problem is not just that large quantities of spent fuel are piling up as several hundred reactors around the world steadily generate tons of them every year, but also the fact that many of these radioactive elements ‘rot’ very slowly, i.e. have very long half-lives. They would continue to be radioactive for tens of thousands or even millions of years and would have to be reliably stored for such durations. This imposes an unprecedented ethical and moral responsibility on current users of nuclear energy - to protect not only themselves, their children and grandchildren from radioactivity but hundreds of generations thereafter.

The storage of spent fuel is a vast and technically complicated subject unto itself, involving such disparate specialisations as nuclear physics, geology, reprocessing chemistry and so on. We cannot begin to do justice to cover that here. But readers are referred to a very lucid, detailed and expert review of both the technology of spent fuel storage and of how different countries are dealing with the problem, published by the International Panel on Fissile Materials (IPFM 2011). As this review points out, already by the end of 2009 there were about 240,000 metric tons* of heavy metal (tHM, mostly uranium) that needed to be stored safely. As of now most of it is stored at reactor sites.

In the short run, the storage problem has been handled well in most countries. After removal from the reactor vessel, the spent fuel rods are first kept immersed for years in large water tanks installed nearby within the reactor complex, until they cool down. After its cooling in water tanks is over, there are two different ways the fuel is dealt with subsequently.

Some countries, like the US, employ the Direct Disposal method whereby, after cooling the spent fuel is removed from the water tanks and kept in dry-cask storage i.e. placed in steel canisters that are surrounded by a heavy shielding shell of reinforced concrete, with the shell containing vents allowing cooling air to flow through to the wall of the canister. These dry casks are then stored within the reactor sites or in some cases in a centralized facility.

Other countries, like India, employ a Closed Cycle program whereby the fuel rods are treated chemically in ‘reprocessing’ units where the fuel is dissolved in acids and the plutonium and...
uranium recovered from it for potential use as reactor fuel. Even after the recovery of Pu and U, there is still a residual ‘high level’ waste which includes the more radioactive elements in the spent fuel. It is this high-level reprocessing waste from spent fuel that requires suitable storage for periods ranging from tens of thousands to up to a million years to minimize the releases of the contained radioactivity into the environment.

It is generally believed that the ultimate storage of the directly disposed of spent fuel and the high-level radioactive waste will require well-designed underground repositories, hundreds of meters deep, where the surrounding rocks and soil will prevent the escape of radioactivity. Most experts believe that this can successfully prevent the escape of radioactive materials to the biosphere for thousands of years.

Turning the particular case of India’s own spent fuel, the problem is still in its early stages since our nuclear program is not as large as those in other industrial nations and consequently there is not much spent fuel to contend with. Typically, about 600–700 tons of spent fuel is generated each year. Our spent fuel policy involves a ‘Closed Fuel Cycle’ wherein we recover the Plutonium and Uranium in the spent fuel rods by, as outlined above, treating them with chemicals in Reprocessing Plants. We have three Reprocessing Plants at BARC, Kalpakkam and Tarapur. The recovered Pu and U which constitute about 97% of the spent fuel is then re-used again as fuel for other reactors.

After separating out the PU and the U, it still leaves behind 2–3% of the spent fuel as ‘high-level waste’ consisting of other radioactive elements. A clear summary of the way India disposes of this high-level waste has been provided in an official statement made in the parliament. As summarized here, the High-Level Liquid Waste is first vitrified, i.e. immobilised into an inert solid vitreous (glass) matrix. Then it is packed in specially designed storage vaults and allowed to cool for a period of 40–50 years. These vaults have so far been stored within the reactor complexes. Eventually, this cooled vitrified waste will have to be disposed of in some geological disposal facility.

That as far as we know is where matters stand on dealing with spent fuel in India. The storage of the high-level waste in dry casks at the reactor complexes should work for several decades. For the long run, as far as we know, no specific location has been identified so far for the geological repository.

11 Hazards of Radioactivity

Finally, let us turn to the subject that, rightly or wrongly, worries a lot of people. The Fukushima reactor explosions had a massive impact (much more than the bigger Chernobyl accident) on public perceptions of radioactive hazards associated with nuclear power. Even though India conducted a full safety review after Fukushima and decided to continue with its plans for expanding nuclear power only after that, it did not assuage the concerns of anti-nuclear activists and NGOs. They organized major protests against the proposed new reactors, especially at Kudankulam where two Russian-built reactors were getting ready to be
commissioned; surprising, since traditionally in India protests were rarely aimed at Russian-built facilities (such has been the impact of Fukushima and the collapse of Cold War behavior patterns). Another site allotted to the Russians at Haripur in West Bengal also has to be relocated because of the opposition from Trinamool Congress party. Similarly, Areva’s EPR reactors planned at Jaitapur on the west coast has been met with local opposition. Protests were also organized during President Hollande’s visit to Delhi. As it happened, even the Kudankulam protests, which were the most sustained anti-nuclear demonstrations that India has seen and which got substantial exposure in the media for several months, could only delay the commissioning of the reactor, and not stop it. Both the reactors at Kudankulam got completed and now generate electricity for the grid.

I will not go into the very interesting question of why such protests against nuclear reactors, or for that matter the far more serious issue of nuclear weapons, have not been successful. But what is relevant to our discussion is the fact that even though these protests could not stop the development of nuclear energy in India, the fear of nuclear radioactivity continues to haunt many members of the public. This fear must be understood and dealt with sensitivity.

I’d think that the public, by now, is inured to witnessing both in their real life and on the television, different types of disasters like fires, earthquakes, chemical explosions as in Bhopal, terrorist attacks and full-scale wars. Why are they so afraid of radioactivity? There are several reasons.

Unlike fires, bullets or chemical burns, with which mankind has been familiar for a long time, nuclear radiation is new and terrifying. It is invisible, has no smell or color.

In many cases of radiation exposure, apart from skin burns, there were few initial signs of the terrible damage that has been done to the interior of the body.

This inability to detect nuclear radiation with the human senses, and the fact that the after-effects of exposure may not develop until years later, has created a near-irrational dread in the public mind.

The grizzly photographs of those killed and injured by nuclear radiation during the Hiroshima-Nagasaki bombings have formed a profound and enduring impression about the horrors of radioactivity.

In many ways, this dread of radioactivity has had a beneficial impact on human society. It has helped develop an unwritten taboo against any nuclear bombings after Hiroshima and Nagasaki. This taboo has held so far and has greatly helped various movements for nuclear disarmament.

But the hazards of radioactivity in the context of a civilian nuclear energy, although they are definitely present, have been greatly exaggerated. Nuclear reactors are not nuclear weapons. Even when they explode, as they did in Chernobyl and Fukushima, the effects are far smaller in intensity by a factor of million as compared to a nuclear bombing. In particular,
in the absence of a major accident, the hazards posed by a normally functioning reactor are truly small. The facts about the extent of radioactive dosage in the environs of a normal functioning nuclear reactor are reliably known (Apte 2014). The annual dose from a typical Indian reactor at a distance of 1.6 km radius varies from 0.0004 to 0.04 mSv (millisieverts).

Compare this with the dosage from other sources:

<table>
<thead>
<tr>
<th>Exposure source</th>
<th>Dosage mSv</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Radiation (one year)</td>
<td>2.4</td>
</tr>
<tr>
<td>One chest X-ray</td>
<td>0.05-0.1</td>
</tr>
<tr>
<td>Typical CAT Scan</td>
<td>7</td>
</tr>
<tr>
<td>Air travel (Delhi to NY and back)</td>
<td>0.2</td>
</tr>
<tr>
<td>Annual Radiation limit (radiation worker)</td>
<td>20</td>
</tr>
</tbody>
</table>

One can see that the radiation dose for the public living in the vicinity is minuscule compared to the other doses of radiation we all receive from the different sources listed in Table 3. DAE frequently points out that villagers who live in areas adjoining the nuclear plants do not seem to have suffered statistically significant incidents of cancer or genetic damage which can be traced to radioactive exposure. For those who tend to distrust such official statements or the technical data in milli-sieverts, let us offer the following compelling commonsense evidence. The thousands of employees working in our reactor complexes do not consist of illiterate citizens who do not know about the possible hazards. They in fact include technically highly trained scientists and engineers. The highest brass in DAE have had their offices located within BARC and other reactor complexes. They have all survived decades of whatever radiation exposure a reactor’s neighborhood carries, lived their full lives, and produced healthy children and grandchildren. This is something sceptical members of the public can easily check since some of the top scientists who have served in DAE are also well-known public figures!

Of course, these comforting arguments hold only when the reactors are functioning normally without any serious accidents. There is no doubt that accidents like the ones at Three-mile Island, Fukushima and Chernobyl (in increasing order of the scale of damage) constitute major disasters. But even there, before deciding policy changes on nuclear industry as a whole because of possible accidents, we have to first find some reliable way of estimating the damage done by a given nuclear accident. After all, we do not close down all chemical plants involving hazardous gases despite the terrible Bhopal tragedy, or all metallurgical production because of the poisonous effluents that it spews into our rivers.
But calculating the likely effects of a reactor explosion is not easy and estimates of human fatality vary widely. At one extreme, there are claims that only about 30 people died due to the Chernobyl accident and hardly one or two due to Fukushima. These seem like absurdly small numbers but they are technically correct if you demand a rigid causal connection of the deaths to the accident. The 30-odd people at Chernobyl were plant workers sent in to clear the mess after the explosion and died later due to radiation sickness. In the case of Fukushima, no one was allowed to go into the reactor building. As a result, there were zero deaths recorded at Fukushima even a week after the explosion.

But in reality, many more people would have died or been seriously affected in the subsequent months and years by the Fallout, i.e. the radioactive particles carried by the winds from the reactor site to the neighboring areas, up to hundreds or even thousands of miles. These deaths, mostly through cancers that take a long time to develop can happen years or decades after the radioactive exposure. While the amount of radioactivity carried to any given location by the Fallout can be measured quite precisely, what is less precise is an estimate of the damage that the radioactive dose would have done in the form of cancers or genetic mutilation. Epidemiological techniques will not be very successful since these cancer incidents will not carry any special signature indicating that they were caused by the radioactive fallout coming from the reactor. They will be buried in the much larger total number of cancer deaths caused by other factors. Therefore, getting a reliable count of such fatalities, scientifically attributable to the reactor accident, will be difficult, except in special situations such as children living in the path of the Fallout who suffer an unusually large incidence of Thyroid cancer.

There are also ‘theoretical’ estimates that biologists can make using models of genetic damage based on laboratory experiments. Here too, models differ. In particular, there are models that assume that there is no genetic damage below some minimum threshold of radioactive dosage. This would imply that in estimating casualties, one can leave out distant regions where the radiation dose falls below that threshold. By contrast in the ‘no-threshold linear models’ any radioactive dosage however small carries some correspondingly small but non-zero probability of causing cancer. These models would estimate a much larger fatality count since it would include an integral over low probability contributions from all distances. There has been much study and scientific discussion about whether there is a threshold or not. In fact, a major study conducted by The US National Academy of Sciences was devoted to addressing such issues. Despite that, not all scientists are convinced of the no-threshold model.

Thus, even in the absence of any contentious political or ideological prejudices, there are genuine scientific reasons behind large differences among estimates of reactor accident casualties. On top of that if we superimpose ideological and professional biases on the part of the die-hard pro- and anti-nuclear commentators then the impact of nuclear accidents can vary wildly from just a handful according to some, to tens of thousands according to others. That can leave even an intelligent layman confused. (For a fuller discussion of the effects of

radioactivity as well as a scholarly critique of India’s nuclear program as a whole, see Ramana (2012).

It would be foolish to claim, as some nuclear enthusiasts do, that nuclear energy is 100% safe. No large-scale high-tech operation ever is. But we have to compare whatever danger is associated with nuclear energy with the hazards associated with other sources of power, their relative advantages and costs. Solar and wind energies are possible alternatives which, in addition to being truly renewable, involve far fewer hazards than nuclear energy. These renewable sources merit a full discussion in their own right and we cannot do that here. In summary, wind energy is already being supported substantially by the Government and by private companies. The problem with wind is that its speed and availability are not in our hands. As a result, the capacity factor of windmill generators is 15–20%. Solar energy was considered too expensive for a long time but in recent years, its prices have crashed and entrepreneurs are coming up with very competitive bids, offering power at amazingly low rates often below ₹3 per unit. The present government is also strongly supporting the growth of solar energy. The Prime Minister has announced a target of 100 GW for solar energy as part of our response to the Paris Accord commitments. If the low costs of renewables like solar and wind energies continue to hold, it may well be that they will soon make up a much larger chunk of our energy basket than nuclear reactors.

But it would be unwise to phase out nuclear energy totally, even in the long run. It carries many advantages such as producing a steady base level input into the electric grind, having a very minimal carbon footprint and occupying much less land area per megawatt than other sources of energy. To the extent that the prospect of another (low-probability albeit dangerous) nuclear accident may legitimately cause concern, it has to be compared with hazards from many other technologies and industries that we live with, to fulfil requirements of modern life. The actual hazards of generating power from any source, whether it be nuclear or carbon-based, have to be balanced in some meaningful way against the hazards of no power. According to some claims, a hundred thousand villages do not have electricity to any significant extent. Unlit roads are unsafe for women, unlit homes and kerosene lamps are bad for children’s eyesight, lungs and education, rural hospitals with constant power breakdowns can be deadly. Has anyone estimated the effective fatalities due to these?

Governments, as well as social activists, must be pro-active in educating the public about nuclear hazards, but in a responsible and balanced manner. Neither bland assurances nor the stoking of hysterical fears will serve the public good. The events at Fukushima have unfortunately damaged, worldwide, the credibility of official assurances in the public’s eyes. At Kudankulam, even personal assurances by Dr. Abdul Kalam, a widely respected and popular past President did not make a significant impact on the protestors. The problem also is that even the general intelligentsia, let alone the lay public, does not have the technical background for making up its own mind about nuclear safety. It has to take someone’s word for it. But, who will give them required assurances when the people best qualified to do so are increasingly disbelieved? So nuclear agencies everywhere, not just India, must work to regain public trust, especially in a democracy.
Finally, a commercial: People concerned about nuclear energy should read the book “India’s Nuclear Energy Program” (INSA 2014) brought out a couple of years ago by Indian National Science Academy, which contains detailed arguments from experts from both sides of the nuclear divide.

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By its very nature, the scientific pursuit is a highly creative and individual undertaking. Today it has also concurrently become a highly collaborative enterprise, requiring the participation of many (sometimes hundreds of) collaborators spread over several disciplines and, depending on the precise investigation, it can also be spread over large geographical distances. Given the nature of this collective and often global activity, it has also become one that would not be possible without considerable social investment.

J. Robert Oppenheimer [1] articulated most eloquently the special obligations that the privilege of doing modern science entails. In 1945, at the conclusion of the Manhattan Project, he addressed the Association of Los Alamos Scientists, those who had worked on this project of exceptional co-dependence. His concluding words were:

I think that we have no hope at all if we yield in our belief in the value of science, in the good that it can be to the world to know about reality, about nature, to attain a gradually greater and greater control of nature, to learn, to teach, to understand. I think that if we lose our faith in this we stop being scientists, we sell out our heritage, we lose what we have most of value for this time of crisis.

But there is another thing: we are not only scientists; we are men, too. We cannot forget our dependence on our fellow men. I mean not only our material dependence, without which no science would be possible, and without which we could not work; I mean also our deep moral dependence, in that the value of science must lie in the world of men, that all our roots lie there.
These are the strongest bonds in the world, stronger than those even that bind us to one another, these are the deepest bonds - that bind us to our fellow men.

Wittingly or unwittingly, this sense of duty and commitment - this conscientiousness - underlies the best of scientific practice in the public sphere. There is, therefore, a requirement for a proper forum [2] for the discussion and dissemination of science, particularly those aspects that have a major impact on social issues. The manner in which it is best done is, arguably, through scholarly articles and reports on matters pertaining to public policy that concern science and technology issues. The scientific community in India has long been interested in such matters in a serious way, engaging with public policy from even before Indian independence although there are relatively few avenues where there can be public discussions of such matters.

Ideas such as self-reliance and the need to secure the benefits of science and technology were already emphasized in the 1958 resolution, and these ideas, in turn, have had a major impact on issues as diverse as public health, the green revolution, animal experimentation, food security and so on.

The engagement between government and the leading scientists in the country has been constant, and many of these consultations have resulted in valuable and comprehensive documents such as the Scientific Policy Resolution of 1958 [3] which laid out the vision of political and scientific leadership on science and technology in India. Ideas such as self-reliance and the need to secure the benefits of science and technology were already emphasized in the 1958 resolution, and these ideas, in turn, have had a major impact on issues as diverse as public health, the green revolution, animal experimentation, food security and so on. Since then, there have been a number of such documents, leading up to the recent TIFAC document, Technology Vision 2035 [4]. However, these have not, as a rule, been as widely discussed, disseminated, and debated in the polity as might have been possible through journal articles. It is telling that national efforts that have gone into producing a large number of reports and position papers [5] have not reached a public forum where issues relating to science and technology education might have been debated widely.

There is an expectation from various quarters that the Science and Technology Academies of India [6] should play a major role in advising and informing governance, especially when it comes to matters that require scientific input. In recent times one of the more public consultations that occurred was in 2009-10 when the issue of introducing the genetically modified vegetable, Bt-brinjal was mooted, a major concern being that this would lead to a loss in biodiversity. After a fierce debate, and despite approval from the Genetic Engineering Appraisal Committee (which since 1986 has effectively granted all permissions to conduct experiments and to eventually allow any commercialisation of the crop) the minister for environment and forests then declared a moratorium "on the release of Bt-brinjal, till such time independent scientific studies establish, to the satisfaction of both the public and professionals, the safety of the product from the point of view of its long-term impact on
human health and environment, including the rich genetic wealth existing in brinjal in our country." [7] This moratorium has not been lifted to date, even though several of the leading scientists of the country, including the then President of the Indian National Science Academy had offered their views to the Government. Indeed, it would appear natural that the science academies should "emerge as the nation’s think-tank, [...] advising the Govt. and the country on issues relating to the development of Science & Technology." [8]. This has not happened with any regularity or any consistency.

We hope that Dialogue will emerge as a unique archival repository of important documents that need to be shared widely and discussed widely.

With this background, the Indian Academy of Sciences’ journal Dialogue: Science, Scientists, and Society [9] aims to provide a forum for summarizing and reporting studies on science and technology policy. We hope that it will emerge as a unique archival repository of important documents that need to be shared widely and discussed widely. There are a large number of journals that cover the areas that we envisage, but these are mainly located in the global north and have a different range of concerns. Given this, one can also hope that Dialogue can also provide a forum for others in the developing world to discuss problems of relevance, and to draw on the experience of colleagues across the globe.

References

1. J. Robert Oppenheimer: ‘We are not only scientists; we are men, too’, 1945. ("Men" in the text of the speech should be understood to also include the large number of women who participated in the Manhattan Project; the usage is a reflection of the times when the speech was written.) A transcript of the entire speech can be found at https://tinyurl.com/6gqxsu.

2. The few journals in India wherein articles on science and public policy include Current Science (Bangalore), the Journal of Scientific Temper (New Delhi) and the Economic and Political Weekly (Mumbai). However, these are not exclusively devoted to policy issues.

3. India’s first Scientific Policy Resolution was issued in 1958 (a copy can be found at https://tinyurl.com/y895wwpo). Subsequent Science and Technology policy statements issued by the Government of India include (a) the Technology Policy Statement 1983 by the Department of Science and Technology (DST) (https://tinyurl.com/y9fi83h4), (b) Science and Technology Policy
2003 by the DST (https://tinyurl.com/yaxpjqcb) and (c) the Science, Technology & Innovation Policy 2013 (https://tinyurl.com/y9smqrb).

4. The TIFAC Technology Vision 2035 Report can be downloaded from https://tinyurl.com/ycocz6qsl. Every year, TIFAC brings out a number of reports that examine technology needs as well as the present status of various different areas. These are available at the TIFAC website, https://tinyurl.com/y93otzb9.


6. These are NASI (the National Academy of Sciences of India), IASc (Indian Academy of Sciences), INSA (Indian National Science Academy), NAAS (National Academy of Agricultural Sciences), INAE (Indian National Academy of Engineering), NAMS (National Academy of Medical Sciences).

7. The summary note by the Ministry of Environment and Forests (MoEF) was reprinted in the daily, The Hindu and can be accessed online at https://tinyurl.com/y9hkkavs. There are numerous other reports, also available online.

8. Adapted from the Mission Statement of the Indian National Science Academy. All the Science Academies [6] have similar objectives when it comes to interfacing with the Government.

9. In addition, there is a closely related moderated online discussion forum, Confluence, http://confluence.ias.ac.in/, that is more adapted to contemporary modes of expression and debate.
On evolution: statement by three Indian science academies

IASc, INSA and NASI

The Hon. Minister of State for Human Resource Development, Shri Satyapal Singh has been quoted as saying that "Nobody, including our ancestors, in writing or orally, have said they saw an ape turning into a man. Darwin’s theory (of evolution of humans) is scientifically wrong. It needs to change in school and college curricula."

The three Science Academies of India wish to state that there is no scientific basis for the Minister’s statements. Evolutionary theory, to which Darwin made seminal contributions, is well established. There is no scientific dispute about the basic facts of evolution. This is a scientific theory, and one that has made many predictions that have been repeatedly confirmed by experiments and observation. An important insight from evolutionary theory is that all life forms on this planet, including humans and the other apes have evolved from one or a few common ancestral progenitors.

It would be a retrograde step to remove the teaching of the theory of evolution from school and college curricula or to dilute this by offering non-scientific explanations or myths.

The theory of evolution by natural selection as propounded by Charles Darwin and developed and extended subsequently has had a major influence on modern biology and medicine, and indeed all of modern science. It is widely supported across the world.

See for example http://www.nas.edu/evolution/TheoryOrFact.html

See this statement in other languages.

See also: Defying both Logic and Biology (in English and other Indian languages)
Evaluate the Evaluations!

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Bad practices seem to spread very rapidly and go to near fixation, making it very hard to subsequently replace them with good practices. Hence they linger long after their ‘badness’ has become widely recognized. Evaluating scientists and scientific papers by the Impact Factors (IF) of the journals in which they are published is one of the most pernicious of such lingering bad practices. In retrospect, it seems shocking that the practice of using IF has become so widely and uncritically accepted. The odds are so heavily stacked against the practice that I would have guessed that it won’t take off the ground. As has been mentioned in many forums, IF measures the impact of the journal and not of the paper, citation practices vary from discipline to discipline and ‘IF pressure’ is sure to lead to bad publishing practices. The bad practices associated with the evaluation procedures go well beyond the use of Impact Factors. Since evaluations are best done by peer groups, the business of eliminating bad practices and ushering in good practices is best attempted as a self-organized process by academics themselves with as wide a participation as possible. Science academies have a critical role in functioning as conscience keepers to usher in good practices and as gatekeepers to keep out bad practices. I believe that science academies around the world are not doing as good a job in this regard, as they potentially can. Recently, three prominent academies, Academie des Sciences of France, Leopoldina of Germany and The Royal Society, London have issued an excellent, joint statement about what they consider good and bad practices. Although the points they make have been repeated time and again, coming as a joint statement from three of the world’s prominent science academies brings with it a certain amount of authority and credibility. Besides, there are some points in this statement that are especially worthy of note. Apart from unambiguously pointing the finger at the excessive use of bibliometric data, the statement suggests reducing the number and frequency of evaluations in the first place; evaluating, training and nurturing the best evaluators, and cautions that the new so-called ‘Altmetrics’ may not be much better after all. I believe that this statement should be widely read by all scientists and hence I am reproducing it below. Nevertheless, it is a statement by three ‘foreign’ academies. Hence, I would urge our own three science academies to seriously study the matter in the Indian context and issue our own statement and
bring to bear the pressure of their authority on the conduct of evaluations in India. Clearly, we need an urgent evaluation of the evaluation process itself
October 27, 2017

Statement by three national academies (Académie des Sciences, Leopoldina and Royal Society) on good practice in the evaluation of researchers and research programmes

1. Introduction

The large increase in the size of the international scientific community, coupled with the desire to ensure the appropriate and efficient use of the substantial funding devoted to supporting scientific research, have understandably led to an increased emphasis on accountability and on the evaluation of both researchers, research activities and research projects (including recruitment, as well as the evaluation of grants and prizes). Given that there is a large diversity of procedures currently used in evaluations which have accumulated over time, it is now necessary to provide some guidelines for best practice in the evaluation of scientific research. Peer review, adhering to strict standards, is widely accepted as by far the best method for research evaluation. In this context, the present statement focuses on the evaluation of individual researchers.

Such an assessment by competent experts should be based on both written (journal articles, reviews, books, book chapters, patents, etc.) and other contributions and indicators of esteem (conference presentations, awards, public engagement activity, peer review activity, datasets shared, seminars, etc.). As a careful evaluation of scientific content and quality by experts is time consuming and costly, the number of evaluations should be limited and only undertaken when necessary, in particular for decisions on competitive academic appointments or funding large projects.

With the increase in the number of evaluations and the emergence of easily accessible electronic databases, the use of bibliometric measures has become an additional tool. However, there has been too much reliance on bibliometric indices and indicator-based tools as measures of performance by many evaluation committees and exercises, leading to the
danger of superficial, over-simplified and unreliable methods of evaluation. This bad practice involving the misuse of metrics has become a cause for serious concern.

Of particular concern are the widely used journal impact factors (IF) which are an estimate of the impact of the journal itself rather than the intrinsic scientific quality of a given article published within it – a point that has been made on several occasions and notably in the San Francisco Declaration\(^{(1)}\). Outstanding and original work can be found published in journals of low impact factor and the converse is also true. Nevertheless, the use of impact factors as a proxy for the quality of a publication is now common in many disciplines. There is growing concern that such “IF pressure” on authors has increased the incidence of bad practice in research and the ‘gaming’ of metrics over the past two decades, in particular in those disciplines that have over-emphasized impact factors. Also, the so-called ‘altmetrics’ – a new form of impact measure – while adding an important and hitherto overlooked dimension to the measurement of impact, suffers from some of the same weaknesses as the existing citation-based metrics.

There is a serious danger that undue emphasis on bibliometric indicators will not only fail to reflect correctly the quality of research, but may also hinder the appreciation of the work of excellent scientists outside the mainstream; it will also tend to promote those who follow current or fashionable research trends, rather than those whose work is highly novel and which might produce completely new directions of scientific research. Moreover, over-reliance on citations as a measure of quality may encourage the formation of aggregates of researchers (or “citation clubs”) who boost each others citation metrics by mutual citation. It thus becomes important to concentrate on better methods of evaluation, which promote good and innovative scientific research.

2. Principles of good practice in the evaluation of researchers and research activities

Essential elements for the evaluation of researchers can be summarized as follows:

2.1. Selection of evaluation procedures and evaluators

Evaluators

Since the evaluation of research by peers is the essential process by which its quality and originality can be estimated, it is crucial to ensure that the evaluators themselves adhere to the highest standards and are leaders in their field. The selection of evaluators should be based on their scientific excellence and integrity. Their scientific achievements should be widely recognised and their curriculum vitae and research achievements should be easily accessible. Such an open process will ensure the credibility and transparency of the evaluations.
Evaluation processes

Since the number of excellent evaluators is limited, the number of evaluation processes should be reduced in order to avoid over-use of first-class evaluators. There is a concern that different agencies and institutions have carried out an excessive number of routine evaluations over the last decades, putting too much pressure on the best evaluators. First-rate evaluators are increasingly reluctant to commit to time-consuming and unproductive evaluation exercises. It is of great importance to reduce the number of evaluations and to confine them to the core issues of research that only peers are able to judge. Evaluators provide a “free resource” as part of their academic duty and this resource is over-exploited. Evaluating bodies must recognise that good evaluation is a limited and precious resource.

A page limit for submissions to all evaluation processes is needed. Excessively long submissions are counter-productive: evaluators need to be able to concentrate on the essentials, which is problematic with very lengthy submissions.

Rotation of evaluators is essential to avoid excessive or repeated influence from the same opinion leaders. The panel of experts should be adapted to reflect the diversity of disciplines or scientific domains. Although gender and geographical distribution will be factors in the selection of evaluating groups, excellence must remain the primary criterion.

2.2. Ethical guidelines and duties of evaluators

Evaluators should clearly declare possible conflicts of interest before the evaluation process. The confidentiality of expert reviews and of the discussions in the evaluation panel must be strictly respected to protect both the evaluators and the evaluated persons.

While reviewers have often learned the practice of evaluation by experience and self-teaching, this competence cannot be taken as given. Methods and approaches to evaluating and reviewing should become part of all researchers’ competence as should the ethical principles involved. Evaluators should be made aware of the dangers of “unconscious bias”. There should, as far as possible, be equivalent standards and procedures for all research disciplines.

The evaluation procedures must also include mechanisms to identify the cases of biased or otherwise inappropriate reviews and exclude them from consideration.

2.3. Evaluation criteria

Evaluations must be based under all circumstances on expert assessment of scientific content, quality and excellence. Publications that are identified by the authors as their most important work, including major articles and books, should receive particular attention in the evaluation. The simple number of publications should not be a dominant criterion.

Impact factors of journals should not be considered in evaluating research outputs. Bibliometric indicators such as the widely used H index or numbers of citations (per article
or per year) should only be interpreted by scientific experts able to put these values within
the context of each scientific discipline. The source of these bibliometric indicators must be
given and checks should be made to ensure their accuracy by comparison to rival sources of
bibliometric information. The use of bibliometric indicators should only be considered as
auxiliary information to supplement peer review, not a substitute for it.

The use of bibliometric indicators for early career scientists must in particular be avoided.
Such use will tend to push scientists who are building their career into well-established/fashionable research fields, rather than encouraging them to tackle new scientific challenges.

For patents a clear distinction should be made between the stages of application, delivery
and licensing.

Success in raising research grant funding should, where relevant, be only one and not the
dominant factor in assessing research performance. The main criteria must be the quality,
originality and importance of the scientific research.

3. Short summary of the main recommendations

Evaluation requires peer review by acknowledged experts working to the highest ethical
standards and focusing on intellectual merits and scientific achievements. Bibliometric data
cannot be used as a proxy for expert assessment. Well-founded judgment is essential. Over-
emphasis on such metrics may seriously damage scientific creativity and originality. Expert
peer review should be treated as a valuable resource.

Reference

PERSPECTIVE

Commonwealth Academies of Science
Statement on Climate Change

Posted with permission from Indian National Science Academy
The world’s climate is changing, and the impacts are already being observed. Changing agricultural conditions, ocean warming and acidification, rising sea levels, and increased frequency and intensity of many extreme weather events are impacting infrastructure, environmental assets and human health. Impacts such as higher rainfall and increased plant growth will be beneficial in some cases.

However, others will be detrimental and felt more widely, changing ecosystems and weather patterns, and disrupting industries, economies, food supplies and livelihoods.

The consensus view of the global climate science community based on current evidence is that avoiding the worst impacts of climate change will require concerted global action to reduce atmospheric carbon.

A target to limit warming to below 2°C above pre-industrial levels was recognised by 160 nations that ratified the 2015 Paris Agreement on Climate Change; a bold and vital step towards addressing climate change.

Meeting this target will require achieving net-zero global greenhouse gas emissions in the second half of the Century followed by active decarbonisation of the atmosphere.

Our work towards this objective has only just begun.

Even if all countries meet their current commitments to greenhouse gas emission reductions, a global temperature rise of more than 3°C above pre-industrial levels is projected by 2100 according to current data.

This would lead to profound impacts affecting billions of people throughout the world.

This challenge needs to be addressed now, and the efforts required will bring enduring social, environmental and economic benefits and opportunities.

Scientific research should continue to inform policy, actions and outcomes. Opportunities for synergies should be taken to address multiple challenges.

Through concerted action, the Commonwealth has the potential, and the responsibility, to help drive meaningful global efforts and outcomes that protect ourselves, our children and our planet.

The Commonwealth academies of science call upon Commonwealth Heads of Government to use the best possible scientific evidence to guide action on their 2030 commitments under the Paris accord, and to take further action to achieve net-zero greenhouse gases emissions during the second half of the 21st Century.

To meet their Paris targets, developed member countries of the Commonwealth will need to achieve net-zero greenhouse gas emissions at or shortly after the middle of this Century. Developing country members may require a longer time frame, and additional support and capacity building.

A range of approaches including pre-emptive and responsive mitigation and adaptation will be required by Commonwealth Nations to achieve this objective.

Recognising different capacities, challenges and priorities, the approaches of each nation will not be the same. But, they must be informed by the best available scientific evidence, monitoring and evaluation.

The academies of the Commonwealth stand ready to assist by providing sound scientific advice on issues relating to climate change.

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PERSPECTIVE

SERB and other sources of extramural support under the Ministry of Science and Technology

M. Vijayan

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SERB and other sources of extramural support under the Ministry of Science and Technology*

M. Vijayan

For decades, the Science and Engineering Research Council (SERC) of the Department of Science and Technology (DST) has been the most important source for competitive research grants in India. The Science and Engineering Research Board (SERB) which recently replaced SERC, has turned out to be less effective than SERC. An impression has gained ground that the Department of Biotechnology is shifting its emphasis from competitive research grants to organizations and institutions. The famed extramural programme of the Council of Scientific and Industrial Research appears to be in jeopardy. Except in a few islands of opulence, most of the scientific research in the country in the non-strategic sector is being carried out using competitive grants. The present crisis in the system for support of such grants bodes ill for Indian science. It needs to be seriously addressed and overcome.

Preamble

Extramural support, especially competitive research funding is central to normal scientific activities. This is particularly so in the case of basic research. Much of scientific research in post-independent India has been carried out using extramural grants with infrastructural support provided by the respective parent research institutions. In addition to the quantum of funding, the mechanism for the use of funds has also been a subject of much discussion. In particular, the need for autonomy in handling research grants was acutely felt. The issue became a subject of active discussion when, in 2005, the erstwhile SAC-PM recommended the setting up of a National Science and Engineering Research Foundation (NSERF). The discussion raged till 2012, when the Science and Engineering Research Council (SERC) of the Department of Science and Technology (DST) was wound up. It so happened that during this period, I was deeply involved with the DST, the Department of Biotechnology (DBT) and the Council of Scientific and Industrial Research (CSIR), the three relevant outfits under the Ministry of Science and Technology. During this period, I was also the Vice-President and then the President of the Indian National Science Academy (INSA). Therefore I have been an active participant in such deliberations. I give below my personal take on these discussions and their aftermath. In addition to putting on record my understanding of the historical facts, I shall also outline my opinion on the current situation of extramural support and views on future course of action.

One or several

There was real or perceived thrust towards setting up a huge monolithic organization combining the extramural mechanisms of all or many granting agencies. There was considerable resistance to and apprehension about creating such a behemoth. Many of us felt that the setting up of such a powerful and all-embracing organization is not conducive to the healthy development of science in the country. Plurality of sources of research funding is absolutely essential. Instead, many of us felt that it would be desirable to have autonomous extramural wings to different granting agencies. In any case, essentially the idea of an all-embracing outfit was shelved. In the report of the Steering Committee for Science and Technology in the Eleventh Five Year Plan (2012), it was mentioned that the NSERF should function ‘as an autonomous body in addition to the existing ministerial mechanisms for funding, which are being administered by the various arms of the Government’. Even this idea was not pursued. Eventually the NSERF was rechristened as Science and Engineering Research Board (SERB), which was mooted effectively as a replacement of SERC. The appropriate legislation on SERB was passed in Parliament in 2008. I personally, like many others, was not enthusiastic about the replacement of SERC by SERB, as seen from the quotation, given below, by R. Ramachandran (Frontline, 28 February–13 March 2009).

‘Noted biologist M. Vijayan, however, preferred to reserve his comments on the SERB. “Its functioning is yet to be seen. Among the systems we have had so far, the SERC and its system of PAC (Project Advisory Committee) certainly worked reasonably well and achieved a healthy growth and spread of basic competitive research. Admittedly, its functioning could be improved; I am not sure whether we need an altogether new body”, he said.

SERC to SERB

Nearly for four decades of its existence DST–SERC was the backbone of extramural support in the country. I, like many others, have been intimately involved with the system. To a substantial extent, I myself and the area of science which I helped to initiate and develop in the country, are products of DST–SERC. With rigorous, but flexible procedures, the system was managed by a wonderful set of officers who exhibited a high level of sensitivity to the problems of scientists, total commitment to work at hand and great competence. During 2005–2012, I was a member of SERC and therefore privy to and contributed to the discussions on SERB. My position at INSA also was a factor in promoting my involvement in the process. A major concern of ours was how to map the positive features of SERC onto SERB. We did everything possible to ensure that.

SERB

SERB has been in existence for several years and the broad outline of its

*Views expressed in this note are those of the author’s only.
functioning is now clear. I doubt if SERB is endowed with the kind of autonomy originally envisaged. Our major concern is to what extent SERB has retained the positive features of SERC and improved upon them.

The most important positive feature that SERB has retained from SERC is the officer corps. Most of these officers, schooled in SERC activities, continue to serve admirably the scientific community under difficult circumstances.

The philosophy of SERC and the associated committees was to support all worthwhile activities. Now I learn that there is a formal or informal understanding that only a certain percentage of the total number of proposals would be funded. This is unwise and militates against the approach that SERC used to follow. Such arbitrary cut-offs should be removed.

SERC used to fund projects adequately, but not extravagantly. Now when I examine the level of funding to projects in areas in which I understand, I suspect that the financial support is often sub-critical. One additional feature which SERB introduced was in terms of clubbing all recurring expenses into one head. This gives the investigator a much needed flexibility. Unfortunately, I understand that this flexibility has now been withdrawn to a substantial extent. It needs to be restored.

SERB was supposed to achieve quick disposal of project proposals. This implied that recommended/approved projects would be sanctioned and money released quickly. However, this has not happened. Often sanction and release of funds are delayed much more than what used to happen under the SERC system.

Under the SERC-PAC system, the relation between investigators and PACs used to be highly interactive. At least in the PAC I have been associated with, most investigators used to be asked to present their proposals before the committee and other investigators gathered at that time. It was rarely that a proposal was turned down without providing adequate opportunity to the investigator to present his/her case. Budgetary details also used to be finalized on the basis of discussions with the investigator. The presentations often used to be made use of as a mentoring exercise. I doubt if such interactive relationship exists between SERB-PAC and investigators.

DBT

DBT has made a difference to Indian biology primarily on account of its extramural programme, although the impact would have been greater had the delivery been more efficient. I have had the privilege of being associated with DBT from its very inception. In fact, I have been associated with the National Biotechnology Board (NBTB), which was the incubant form of DBT. Recently, an impression has gained ground that the emphasis of DBT is shifting from extramural research to organizations and institutions. I hope that this is a false impression.

CSIR

CSIR is a great organization which has served the country with distinction for more than 75 years. It is a highly under-rated organization. Its extramural programme has touched the lives of many Indian scientists, including myself. Its laboratories straddle the strategic and non-strategic scientific activities in the country. I deem it a privilege to have worked closely with CSIR, including as a member of the CSIR Society and its Governing Body. Unfortunately, the extramural programme of CSIR is now only a pale shadow of what it was originally. CSIR itself appears to be under constant unfair attack.

The way ahead

SERC used to be a jewel in the crown of DST. In the present scheme of things, is DST expected to have the same commitment for SERB as it had for SERC? Is SERB empowered to act on its own, especially in financial matters, including receiving funds, independent of DST? Are there mechanisms to ensure that SERB is not orphaned in difficult situations? Perhaps answers to these questions exist or clarity on them are yet to emerge.

The immediate task is to raise the functioning of SERB to the level that existed in the case of SERC. It should be ensured that all worthwhile projects are funded adequately. This would not involve spreading the butter thin, as there are not that many good projects available in the country. This can be done perhaps through an additional outlay of a couple of hundred crores of rupees, which is very small in the overall context of S&T expenditure. The interactive mode involving the PACs and investigators as well as the mentoring role of the PACs need to be restored. Not only that the funding mechanism should be as flexible as that of the erstwhile SERC, new flexibilities should be introduced. The clubbing together of all the recurring expenses into one head would be a step in the right direction.

The primacy of extramural funding, including competitive research grants, in the activities of DBT needs to be maintained and further strengthened. Perhaps the procedures used earlier by SERC could be profitably adopted by DBT. In any case, the system should be made more efficient.

CSIR should be protected and strengthened. Its extramural support programme needs to be restored to its old glory.

The outlay for S&T research in the country is very low. It is a little over 0.8% of the GDP as against around 2% in China, a country which in many ways is comparable to India. Furthermore, the GDP of China is much higher than that of India. Out of the total S&T outlay, the amount set apart for extramural activities, including competitive research funding, constitutes a small portion. Very often, in difficult situations, even the small outlay for extramural research funding is reduced. This is unfortunate. We need to design or devise measures to maintain at all times support for extramural research at a reasonable level and to enhance it periodically.

Concluding remarks

My intention in writing this note is not to find fault with anybody. I am fully conscious of the constraints under which our colleagues associated with the government work. In fact, my hope is that this note would be of some small help to them. Except in a few islands of opulence, much of the research in the non-strategic sector is carried out using extramural support from granting agencies. Therefore, measures to maintain and enhance the level of extramural funding are urgently called for. All of us need to work towards this end.

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A Policy Statement on “Dissemination and Evaluation of Research Output in India” by the Indian National Science Academy (New Delhi)

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A Policy Statement on “Dissemination and Evaluation of Research Output in India” by the Indian National Science Academy (New Delhi)

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Considering the necessity of common and objective parameters of assessment of research outputs, the Indian National Science Academy (New Delhi) has, after extensive deliberations involving its entire fellowship, issued this policy statement on Dissemination and Evaluation of Research Output in India. It is expected that this will be adopted and implemented by different agencies/regulatory bodies in India.

Executive Summary

1. Introduction

Research adds to human knowledge by addressing well-posed questions about the unknown. Science progresses only when a new discovery is subjected to thorough peer-review and further validated by the community. Since similar and over-lapping questions in a given knowledge domain would be bothering many, an element of competition has resulted in scientists wanting to quickly disseminate their results. Research output is also ‘owned’ by the disseminating researchers, as implied by the fact that research papers are not published without author names. The increasing numbers of authors and, therefore, increasing competition, technological advances in the methods of dissemination of information and the inevitable geo-political biases have had a great impact on the research output dissemination process, which is largely in the form of research journals. Developments on the internet in recent decades have allowed dissemination of research findings without delay and with a much higher potential for better visibility than before.

Translational research, our ability to attract young generation to participate in intellectually challenging research as a way of life, and finally the prestige of the country’s research community, are largely dependent on the ‘basic’ research carried out in country. Therefore, development of appropriate criteria for assessment of basic research is very important. In the absence of well thought out policies, mediocrity prevails. One such example is the alarming rise of predatory journals and predatory conferences in the country and elsewhere.

The perceived importance of the research output is used in the evaluations of an author’s and/or an institution’s research contributions. While research leading to patents can be assessed on the basis of exploitation of the patent by industry etc., an objective assessment of basic research presents many challenges.

2. Need for a Consistent Policy on Dissemination and Evaluation of Research Output in India

The research output from India has increased remarkably in recent decades, thanks to increasing investments in, and expectations from, R&D activities. This has also led to increased demands on methods to assess the quality and quantity of research output of an individual and/or institution. Besides the serious limitations of the

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various bibliometric parameters used for the diverse assessments, the methodologies and parameters applied by
different agencies in the country also show significant inconsistencies. Inappropriate guidelines about assessment
by different agencies and their misuse have seriously vitiated the research output and assessment scenario in
the country. Therefore, it is necessary to develop common policies that promote healthy practices for dissemination
and evaluation of research output in the country.

This document discusses and recommends basic policy parameters about the following issues: i) Promotion
of a pre-print archive publication policy, ii) Promoting journals published in India, iii) Minimizing predatory journals
and predatory conferences in the country, iv) Policies for categorizing and evaluating research efforts, and v) Policies for payment of ‘open access’ charges and publication of conference proceedings, specifically in Indian context.

3. Preprint Repositories and Peer Review after Dissemination

Preprints archives provide ‘gold open-access’ for sharing un-peer-reviewed manuscripts with scholarly community
in the given field prior to formal publication. Such platforms, providing eternal ‘gold-open-access’, ensure not
only the claim for priority, but also facilitate informed feedback from a large number of peers which can be
helpful in preparing articles for formal publication. The current common practice of listing submitted or in
preparation manuscripts in grant applications/nominations for awards etc, permits the assessors neither to learn
about the actual contents of the manuscript nor to access peer reactions, and thus precludes an objective
evaluation. Open accessibility of manuscripts on Pre-print Archives facilitates their objective assessment.

Recommendation

3.1. Various agencies/organizations in India that fund research should take cognizance of articles that
have been deposited in established free open access Pre-Print Archives as a proof of prior-data. However, for further evaluation of author’s contributions for assessment etc., peer-reviewed publication is important.

4. Promoting Journals Published in India

In order to improve the ranking of research carried out in India, there is an urgent need to have good international
recognition of research/review journals published in India. This requires appropriate encouragement to our
academic community to also submit their quality research papers to journals published in India, especially those
that are published by established academies, societies etc, have long standing history of publication and follow
good policies and practices of peer-review and publication process.

Recommendations

4.1. No agency should ask separate listing of research publications in ‘National’ and ‘International Journals’.

4.2. It is essential to take steps to enhance the visibility of established Indian journals by proactively
encouraging researchers in the country to publish some of their papers in these journals.

4.3. Papers published in established Indian journals may even be given special attention during any
assessment if their citation significantly exceeds the average citation rate of the journal.

5. ‘Publish or Perish’ Policy, Open Access Charges and Evolution of So-Called Predatory Journals

The increasing use of scientometric parameters for assessing individual’s research contributions and institutionalized
norms for certain minimal numbers of publications to be mandatory for eligibility for faculty appointment/promotion
etc have fuelled the rush to publish. This has been exploited by unscrupulous business interests resulting in
mushrooming of ‘predatory journals’ and ‘predatory conferences’. Such sub-standard journals and conferences
need to be positively discouraged.

**Recommendations**

5.1. The academic community, especially the young research scholars and faculty need to be sensitized about predatory journals and conferences so that they do not fall prey to such un-academic activities.

5.2. Funding agencies should advise the concerned investigators to refrain from publication/participation in predatory and substandard journals (i.e., those that started publishing only as online journals in recent past, levy open-access or other charges, assure rapid publication and have ambiguous peer-review process and publication policies) and conferences. Such publications and participations must not be counted as research output.

5.3. Funding agencies and institutions should not generally provide funds to the conference organizers for independent publication of the proceedings of a conference/seminar unless the conference is meant to be a brainstorming to review the status of a field and to plan future directions.

5.4. Payment of open access charges, except in case of publication in well established journals of repute, may be generally avoided.

5.5. Articles placed on established pre-print archives, which provide perpetually free access to all, should be encouraged.

5.6. Emphasis has to be on quality rather than quantity.


The inevitable assessment and evaluation of research output of an individual or an institution over a period of time has entailed a large variety of scientometric or bibliometric parameters. Despite the serious questions about the journal impact factor and other similar metrics by academic bodies across the world, such measures continue to be formally used in India leading to unhealthy competition and assessment.

**Recommendations**

6.1. Assessment of an individual’s research contributions should primarily be based on the impact of what is published rather than on where it is published. The ‘impact factor’ of a journal must not be used as the primary indicator nor should it be used in isolation.

6.2. Instead of assessing on numbers of papers published by an individual, assessors should find out if the research output was only confirmatory in nature or led to incremental or path-breaking advances.

6.3. Each of the ‘best 5’ papers identified by candidate/nominator should be categorized as ‘confirmatory’, ‘incremental advance’ or ‘path-breaking advance’. Identification of a work as ‘path-breaking advance’ should be justified by (a) explicit citations from non-overlapping authors or (b) brief statement as to why the applicant/nominator considers the given work as ‘path-breaking’.

6.4. In cases of multi-authored papers, specific contribution by the applicant/nominee in the given paper should be clearly identified for assessment.

It is believed that the above suggested policies on dissemination and evaluation of our research output would promote quality basic research and help develop scientific temper in the country.
1. Introduction

Research adds to human knowledge by addressing well-posed questions about the unknown. Since similar and overlapping questions in a given knowledge domain would be bothering many, an element of competition in finding answers often becomes an essential component of research. The need for a quick dissemination of the research output is thus a natural consequence of this competitive profession. Research output is also ‘owned’ by the disseminating researchers, as implied by the fact that research papers are not published without author names! The perceived importance of the research output is, therefore, used in the evaluations of an author’s research contributions.

The increasing numbers of authors and, therefore, increasing competition, technological advances in the methods of dissemination of information and the inevitable geo-political biases have had a great impact on the research output dissemination process, which is largely in the form of research journals. Developments on the internet in recent decades have allowed dissemination of research findings without delay and with a much higher potential for better visibility than before.

A widely accepted and followed principle requires that any claim of a new knowledge addition should be independently verifiable. Dissemination is a prerequisite for wider validation. However, current models also require some validation prior to the actual dissemination of new findings to the community. The practice of review by peers prior to wider dissemination, in vogue for a few centuries, serves to ensure the scientific soundness of the research output being reported. There is an increasing debate in recent times (see HCSTC, 2011; Baldwin, 2017) regarding possible bias in favour of papers submitted from established institutes, and about reviewers being biased towards established ideas and thus stifling innovation. This has raised serious concerns about the current system of pre-dissemination or pre-publication peer review being really objective enough to provide a rational validation. The pre-publication peer-review does not necessarily ensure a rational and complete validation because, besides the above concerns, errors in the manuscript may be missed by the limited number (typically 1 to 4) of experts who see the manuscript. The increasing number of manuscripts being submitted to increasing numbers of journals limits the availability of reviewers and often those who become available are not able to or willing to provide the required time and effort. Even fraudulent data have been published in the most respected journals. Such attempts are usually due to one or the other kind of material benefits to researchers that follow their publication. There have been reports (Woolston, 2014) that journals with higher perceived prestige value also have higher retraction rates! This has been attributed, on the negative side, to authors being less honest and cutting corners to get a publication in such prestigious journals. On the positive side, this has also been attributed to higher visibility of the given journal resulting in a higher level of scrutiny. Such retractions of published papers are examples of post-dissemination (or post-publication) review at work. It follows that dissemination without delay but with a high level of visibility ensures both (i) ownership of the researchers and (ii) a proper post-dissemination validation and evaluation of the research output. Validation of major path-breaking research output has always been linked to the post-publication acceptance by the community of researchers in the field, and not just to its being published in any journal, however ‘reputed’ it may be.

Developments on the internet in recent decades have allowed dissemination of research findings without delay and with a much higher potential for better visibility than before. Researchers now access the contents page of the post-publication review at work. It follows that dissemination without delay but with a high level of visibility ensures both (i) ownership of the researchers and (ii) a proper post-dissemination validation and evaluation of the research output. Validation of major path-breaking research output has always been linked to the post-publication acceptance by the community of researchers in the field, and not just to its being published in any journal, however ‘reputed’ it may be.

The easy availability and the perceived conveniences of reading a soft copy is rapidly resulting in extinction of hard copies. As discussed later, the
multiple conveniences of the availability of soft copies of published work on internet have also entailed several serious concerns.

Publishers have also been influenced by developments in the internet. The online submission of a manuscript makes it instantaneously available to editor and reviewers. The practice of ‘ahead of print’ online publication, increasingly followed by publishers, has enhanced the speed with which readers can read and comment upon the findings and thus influence the impact of new findings. In some cases, this has also resulted in corrections being incorporated in the final version after the corrected proofs were available online. Although a post-publication review has always existed, the internet has made it an effective alternative to the usual pre-publication peer review (HCSTC, 2011).

2. Need for a Consistent Policy on Dissemination and Evaluation of Research Output in India

Translational research, our ability to attract young generation to participate in intellectually challenging research as a way of life, and finally the prestige of the country’s research community, are largely dependent on the ‘basic’ research carried out in country. The perceived importance of the research output is used in the evaluations of an author’s and/or an institution’s research contributions. While research leading to patents can be assessed on the basis of exploitation of the patent by industry etc, an objective assessment of basic research presents many challenges. Therefore, development of appropriate criteria for assessment of basic research is very important. In the absence of well thought out policies, mediocrity prevails. One such example is the alarming rise of predatory journals and predatory conferences in India and elsewhere.

Research output from India has increased remarkably in recent decades, thanks to increasing investments in, and expectations from, R&D activities (Pohit et al., 2015). This has obviously led to increased demand on methods to assess the quality and quantity of research output of an individual and/or institution.

A variety of bibliometric parameters like the Journal Impact Factor, Citation Index, H-index etc have been widely used in India. Several recent reports (Lakhotia, 2010; Chaddah, 2014a, 2015; Noone, 2016; Bornmann and Marx, 2016; Elango and Ho, 2017; van Leeuwen and Wouters, 2017) have discussed the limitations and even undesirability of application of most of these parameters for assessment purposes. Besides the limitations of the various bibliometric parameters being used for the diverse assessments, the methodologies and parameters used by different agencies in the country show significant inconsistencies. Inappropriate guidelines about assessment by different agencies and their misuse have also seriously vitiated the research output scenario in the country. Notwithstanding the fact that no method of assessment can be completely free of subjective judgments, it is necessary that these issues are discussed to develop policies that promote healthy practices for dissemination and evaluation of research output in the country.

This document discusses and recommends basic policy parameters about the following issues: i) Promotion of a pre-print archive publication policy, ii) Promoting journals published in India, iii) Minimizing predatory journals and predatory conferences in the country, iv) Policies for categorizing and evaluating research efforts, and v) Policies for payment of ‘open access’ charges and publication of conference proceedings, specifically in Indian context. It is believed that these recommendations would be helpful to the growth of quality research in the country and elsewhere.

3. Preprint Repositories and Peer Review After Dissemination

Preprints are un-peer-reviewed manuscripts which authors use to share their current results to the scholarly community in their field prior to formal publication so that they can not only claim priority, but also get informed feedback from a large number of peers that is expected to be helpful in revising and preparing articles for submission to a journal for formal publication. Preprint archives provide a platform for permanently storing soft copies of such manuscripts with open access to any interested person. In this ‘gold open-access’ mode of dissemination, neither the author nor the reader is charged. Even prior to the internet, some specialist groups did circulate preprints as an extension of a seminar to an audience that could not be physically present. For example, the High-T_C Newsletter used to be delivered by post and contained
Praveen Chaddah and Subhash C Lakhotia

4. Promoting Journals Published in India

One of the major concerns of Prof. C V Raman while

...
launching Current Science was that unless the country has its own high quality research journals, the quality of science in the country would not be high. Due to initiatives taken by scientists of yesteryears, a large number of research journals are being published, uninterrupted over decades, in India. Unfortunately, most agencies that fund, recruit or reward, ask the applicants to provide separate lists of publications in ‘National’ and ‘International Journals’ (Lakhotia, 2013). An implied outcome of such distinction is that papers published in the ‘national’ journals are poorer than those in ‘international’ journals. Such unjustified implication has resulted in most of the so-called ‘national journals’ being trapped in the vicious circle of submission of poor quality manuscripts by the community and consequent low recognition and citations and therefore low-impact factor (Lakhotia, 1990, 2013, 2014), although it is also true that in times of strong competition, many have resorted to Indian journals. Most of the traditional Indian journals do not charge from authors, and provide free full-text access on the internet. It is essential to take steps to enhance the visibility of these journals by proactively encouraging established researchers to publish some of their papers in journals, especially those that are published by established academies, societies etc.

Papers published in established Indian journals may even be given special attention during any assessment if their citation significantly exceeds the average citation rate of the journal.

Recommendations

4.1. No agency should ask separate listing of research publications in ‘National’ and ‘International Journals’.

4.2. It is essential to take steps to enhance the visibility of established Indian journals by proactively encouraging researchers in the country to regularly publish some of their research outputs and other articles in these journals as well.

4.3. Papers published in established Indian journals may even be given special attention during any assessment if their citation significantly exceeds the average citation rate of the journal.

5. ‘Publish or Perish’ Policy, Open Access Charges and Evolution of the So-called Predatory Journals

The advent of internet and very fast growth of the world-wide web has transformed research publication process. Publishing has become faster and easier. At the same time the volume of research papers being published has become very large, thanks to the rapidly increasing number of researchers and increased demands on them to publish or perish. Consequently, research publication has become an industry with enormous commercial interests. Contrary to the expectation that spread of internet and replacement of hard-copy journals by the online soft copy versions would make the dissemination of research outputs less expensive and thus benefit a wider audience, the ever-increasing subscription costs have resulted in the earlier practice of ‘reader pays for reading a paper’ to ‘author pays for being read’ model. The ‘open access charge’ that the author or his/her institution or the supporting agency is required to pay in this model is not trivial so that even for a reasonably funded researcher in India, it can be a substantial drain on the grants available for research. Generally, higher the rating/prestige of a journal, higher is the open access charge that the author needs to pay. Apparently the profit margins are very high (Lakhotia, 2017). Even professional learned societies use profits from publications for other academic and professional activities.

The increasing use of scientometric parameters for assessing individual’s research contributions and institutionalized norms for certain minimal numbers of publications to be mandatory for eligibility (e.g., the current UGC regulations for minimum standards for Ph.D. or faculty appointment/promotion etc.) have fuelled the rush to publish. Unscrupulous business interests have exploited this situation resulting, especially during the past decade, in mushrooming of the so-called ‘predatory journals’ (Beall, 2012; Lakhotia, 2015, 2017a, 2017b, Patwardhan et al., 2015; Clark and Thompson, 2016; Jayaraman, 2017) which publish anything for a fee. Since prestigious journals often charge hefty amounts (can be as high as a few lakh Indian Rupees) per accepted open-access paper, there is plenty of ‘room at the bottom’ for the other publishers to exploit the needy and gullible authors. These publishers cannot be wished away;
they wreck havoc with our existing evaluation system and must be contained and countered by evolving our evaluation system. India, unfortunately, is one of the leading countries in publication of such journals, thanks to some mis-guided and ill-implemented policies (Priyadarshini, 2017).

The DBT and DST Open Access Policy seeks open-access for all publications resulting from their funding, but recognizes that the authors are restricted by time-embargoes that are imposed by many foreign publishers even on manuscript versions. The efficacy and popularity of the repositories created under this Policy needs to be enhanced (Chaddah, 2016b). It may be noted in this context that most journals published by academies and established academic societies in India are fully open-access, without any charge to authors or readers, and thus impose no restrictions on their archiving on open repositories.

Parallel to the worrying scourge of predatory journals, there has been a rapid and widespread emergence of “predatory conferences” (Lakhotia, 2015, 2017a; Cobey et al., 2017), which like the predatory journals, only help the ‘predator’ organizer to earn money from the ‘prey’, who ‘earns’ the required points to fulfill/improve the minimal ‘academic performance index’ (API) score defined by the University Grants Commission, New Delhi. Those who register for such predatory conferences are also assured of ‘publication of paper in UGC-approved Journals’ or as a chapter in conference proceedings based e-book with ISBN, besides ‘Presentation & Publication certificates’. Such fraudulent exercises have no academic merit and yet help the person meet certain UGC norms, which ironically were put in place to promote quality academic activities.

Even some traditional conferences that have been regularly held since many years, have recently started publishing Proceedings through reputed publishers who charge a hefty amount, and put in a note that papers have been reviewed by the conference organizers. Such conference proceedings are hardly cited, but preclude submission of the work to standard journals. Thus not only the new knowledge fails to be properly disseminated but remains susceptible to possible plagiarism (Chaddah, 2016a). Such journals and conferences need to be positively discouraged.

**Recommendations**

5.1. The academic community, especially the young research scholars and faculty need to be sensitized about predatory/substandard journals and conferences so that they do not fall prey to such un-academic activities.

5.2. Funding agencies should advise the concerned investigators to refrain from publication/participation in predatory and substandard journals (i.e., those that started publishing only as online journals in recent past, levy open-access or other charges, assure rapid publication and have ambiguous peer-review process and publication policies) and conferences. Such publications and participations must not be counted as research output.

5.3. Funding agencies and institutions should not generally provide funds to the conference organizers for independent publication of the proceedings of a conference/seminar unless the conference is meant to be a brainstorming to review status of the field and to plan future directions.

5.4. Payment of open access charges, except in case of publication in well established journals of repute, may be generally avoided.

5.5. Articles placed on established pre-print archives, which provide perpetually free access to all, should be encouraged.

5.6. Emphasis has to be on quality rather than quantity.


Assessment and evaluation of research output of an individual or an institution over a period of time is inevitable in the current competitive world. A large variety of methods and metrics have been developed leading to emergence of new disciplines like Scientometrics or Bibliometrics. Each of the methods and metrics that have been advocated has its own limitations and associated controversies. Despite the fact that the journal impact factor has been seriously
questioned by academic bodies across the world (Lakhotia, 2009, 2013, 2014; Johnston, 2013; Jacobs, 2014, Callaway, 2016; Kiesslich et al., 2016), this measure continues to be formally used in India, as evident from the fact that most assessment forms/nomination forms, ask for IF of the journals where the research has been published.

Research output of an individual and/or institution has to be evaluated by the impact it makes. The first measure of the impact is how many people read the paper. The metric giving the number of downloads is made available by many journals; the pre-print archives also provide this metric. This metric is generally not used as a measure for evaluation because the download is anonymous with no hint of the reaction on reading. This metric can, nevertheless, provide some indication of readers’ interest in the paper. The other measure of impact is if the paper is relevant enough to be cited. This metric (Citation index) is currently used for evaluating a paper. It is also used for evaluating a researcher; either directly through the citation index or through h-index, both of which have their own limitations and associated controversies (Chaddah, 2014a). Another measure of impact of a paper is if it changes the research of other researchers, it would be cited/discussed extensively and/or multiple times in a paper by non-overlapping authors. This metric is presently not generally available, but would be easy to be made available.

The evaluation process must distinguish between ‘confirmatory’ research and research that leads to ‘incremental’ or ‘path-breaking’ advance. The citation profile vs time is different for different levels of ‘novelty’ (Stephan et al., 2017). This is obvious because in most cases, out-of-the-box novel ideas take time to be accepted. The time-profile of citations, a metric that is readily available, can be used in conjunction with the frequency with which the paper is cited in papers of non-overlapping authors.

While evaluating a researcher, we also need to look at the body of work. The work could be of the ‘hit-and-run’ variety, with few papers on many different topics. Or it could have concentrated on a few problems, which could have even created new directions and/or keywords. In this case papers by non-overlapping authors would cite many papers of the same author/s. ‘How many papers of an author are cited in one paper of non-overlapping authors?’ is thus another relevant metric.

While evaluating the research output of a researcher (as also of an institution), we need to move away from ‘where did you publish’ to ‘what did you publish’ so that instead of calculating the journal’s impact factor, we actually look at what is published and what impact it had or may have on other researchers.

**Recommendations**

6.1. **Assessment of an individual’s research contributions should primarily be based on the impact of what is published rather than on where it is published.** The ‘impact factor’ of a journal must not be used as the primary indicator nor should it be used in isolation. Information about Impact Factor of the journal where a paper is published should not be asked for.

6.2. **Instead of assessing on numbers of papers published by an individual, assessors should find out if the research output was only confirmatory in nature or led to incremental or path-breaking advances.**

6.3. **Each of the ‘best 5’ papers identified by candidate/nominator should be categorized as ‘confirmatory’, ‘incremental advance’ or ‘path-breaking advance’.** Identification of a work as ‘path-breaking advance’ should be justified by (a) explicit citations from non-overlapping authors or (b) brief statement as to why the applicant/nominator considers the given work as ‘path-breaking’.

6.4. **In cases of multi-authored papers, specific contribution by the applicant/nominee in the given paper should be clearly identified for assessment.**

**7. Concluding Remarks**

This document has covered two aspects viz. dissemination of research output, and evaluation of research output. Dissemination is necessary for validation, a pre-requisite for the output to be accepted as an addition to human knowledge. Dissemination must also ensure ownership of the output, and prevent
its being plagiarized before this ownership is accepted and registered. Assessment of the quality of new knowledge created through research is not a straightforward process and no single method can become error-proof. The most important and essential component is that the assessors understand the nature and significance of the contributions, rather than rely on empirically defined scientometric parameters. It is expected that the present recommendations would provide for objective assessment and thus be helpful to the growth of quality research in the country and elsewhere.

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

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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 parlance 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. 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.

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 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 financiers 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. 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. 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). 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

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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 popularizers 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 ‘fairytales’ 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 outreach programs lead to a somewhat ritualistic observance of public outreach programs.
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 a 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. 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, Birdhouse Network program, Seed Preference Test by Cornell Lab of Ornithology, National Institute of Invasive Species Science program, Monarch Larva Monitoring Project, 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 JJ), 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. 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. 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 ‘Crayfs’ project where the goal is to engage public into a cosmic ray source localization program using smartphones (Whiteson et al. 2014). In 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.

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). 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). Public agencies have also been 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.

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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. 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. 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. 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 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 – 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

\[18\] Web source: http://aipsn.net/
\[20\] Web source: http://www.nscat.org.in/
\[21\] Web source: JyotirvidyaParisanstha/JVPs, http://jvp.org.in/
\[23\] Web source: www.imsc.res.in/triveni/2018/
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.

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References


Now that the Government of India has decided to set up the Higher Education Commission of India (HECI), it is time to look at the challenges ahead.

The University Grants Commission (UGC) will cease to exist. All India Council of Technical Education (AICTE) and the National Council for Teacher Education (NCTE) will continue to function. National Assessment and Accreditation Council (NAAC) will continue too.

The proposed Act delineates the regulatory authority and the means of fund allocation. UGC will be replaced by HECI without financial responsibility. The fund release will be directly under the control of the Ministry of Human Resource Development (MHRD). The result will be a nightmare.

MHRD is already distributing funds to IITs, NITs, IISERs and other institutes of national importance. Distribution of funds to the central universities will be much more demanding on MHRD. State universities need funds too. UGC was doing much more than just releasing funds, albeit with limited efficiency.

The proposed draft emphasizes on the functional autonomy of the universities and deemed universities and at the same time gives the regulatory body the powers to “authorise” the existing institutions to continue or close down within a period of three years. HECI will lay down the guidelines for the award of degrees and publish the curriculum to be followed by academic institutions. One nation, one curriculum does not work. India is a diverse country and we need enormous flexibility in formulating curricula.

The proposed draft outlines what HECI would do in terms of review and the actions that it could take. Annual review is unrealistic and is likely to become a ritual. Review every five years is more realistic. The clause, “The Chief Executive and other members of Management of
such institution who do not comply with the penalty imposed by the Commission shall be liable for prosecution as per procedure laid down under the Criminal Procedure Code and may be punished with imprisonment for a term which may extend up to three years” is draconian and goes against the spirit of autonomy.

In terms of numbers, India has done well in educating the masses in the last seven decades after independence, as is evident from the reports of All India Survey of Higher Education (AISHE) published by MHRD each year. The bottom of the pyramid has been enlarged to ensure gender equity and societal inclusiveness to ensure that the socially disadvantaged are given a helping hand to move up the ladder. The next task is to improve the quality of education and infrastructure for teaching as well as research to reach the pinnacle of excellence. This requires massive input in terms of funds to improve the basic infrastructure in central as well as state institutions. Unless the quality of education and the infrastructure (laboratories) is improved at the college level and the university level, leaders of science and technology and arts and humanities will simply not emerge!

A closer look at individual institutions would reveal that the infrastructure in many state and central universities is appalling. Efforts have been made over the years to remedy the situation through the Fund for Improvement of S&T Infrastructure in Universities and Higher Educational Institutions (FIST) operated by the Department of Science and Technology, New Delhi. But the rules of the game made it clear that the funds could not be given for buildings and other basic infrastructure. Equipment grants made sure that basic equipment was available in most of the colleges and universities. But the improvement in the basic infrastructure has not kept pace with changing times.

A look at developed countries would reveal that the difference in infrastructure between the top institutions and the institutes down the line is limited. Regardless of where a student joins, certain minimum quality of education is guaranteed in those institutes.

India is still a developing Nation, eager to become a developed Nation. The purpose of this Editorial is to state what is needed to be done if we wish to take advantage of the demographic dividend and emerge as a leading scientific and technological warehouse.

We need to invest heavily, not just in top institutions, but from bottom up. Demolish/renovate old buildings (some of them have the heritage tag) and make all laboratories state of the art. Higher Education Financing Agency (HEFA) loans would not do!

Setting up Institutes of Eminence is essential, but this also requires that the basic infrastructure in the feeder institutes (read colleges and universities) is improved. Let us not forget the old dictum: quality input begets quality output. Quality faculty will ensure quality graduates and they in turn will ensure quality faculty input into the system. There is a convective relationship between quality students and quality faculty.

There is an urgent need to internationalise our academic institutions. We need to actively admit foreign students and appoint foreign faculty. We must make our campuses conform to global standards. Safety in the laboratories is not an option. It is a way of life. During my visits
to neighbouring countries, I found that they are eager to send their students to India for higher education. If they could get scholarship, it is even better. There are scholarships available, in principle, to students from SAARC nations. But nobody seems to know how to go about applying for them.

One can make estimates of the amount of funds required to improve the basic infrastructure in all academic institutions. Miracles do not happen. We need to plan and invest over a period of time, in a systematic manner. Very quickly the argument gets diverted into state versus centre. The Centre has to ensure that funds are provided to central as well as state institutions. The taxpayer has been paying educational cess over the years. This can be made use of.

Recently, there was a big news about UGC granting autonomy to many institutions. Acts and Statutes of many institutes provide autonomy to them. This has been eroded over the years. This has to be restored across the board. Autonomy is needed in admission of students and in designing the curriculum with changing times. Institutions of national importance have used their autonomy in ensuring quality education and research over the last five decades.

Ensuring quality in academic institutions has to start with the appointment of quality educationists as Directors and Vice-Chancellors. Search cum Selection committees have been reduced to Selection Committees. Candidates are expected to apply. Many qualified and deserving candidates would simply not apply.

In many institutes, funds allocated are not utilised in time, thanks to archaic purchase procedures. The Government is fully aware of the problem with L-1 (lowest quotation). Administrators are afraid of taking decisions as they are afraid of audit objections and reference to the Central Vigilance Commission. Best practices elsewhere have to be adopted in Indian institutions in a time bound manner, if we are serious about saving them.

In most of the Indian institutes, the research done is incremental in nature. Colleagues should be encouraged to take risk in undertaking projects that are in frontiers of science and technology. This can happen only in an atmosphere of trust and freedom.

It is time to let the society know what we are doing. There is a need to increase the outreach programmes in each institute. Students from all walks of life should be encouraged to visit individual labs and institutions so that they would come back for higher studies. Many institutes find their “open house” programmes a big success. Busloads of students and teachers and parents come visiting. They are curious to know what is happening in the citadels of learning. If the public is convinced, the government will have no choice except to increase funding for academic institutions.

Summary: decentralise and deregulate higher education; appoint able leaders as Directors and Vice-Chancellors; give them training in academic administration and financial management; provide adequate funds; come up with user friendly GFR for academic institutions; keep
decisions of academic institutions outside the microscopic purview of the Government and Judiciary.

*Autonomy is essential in all aspects: autonomy in recruitment, in admission, in curriculum and in functioning.*

India’s strength is its diversity. There is a need to diversify the *structure* to meet the aspirations of the students from various backgrounds. There is no need for everybody to become an engineer or a doctor. The country needs scientists, sociologists, philosophers, economists, historians, artists, linguists,... It will be a pity if all academic institutions become IITs.

*Teaching and research* have to go hand in hand. For practical reasons, colleges will continue to focus on teaching, but research has to become an integral part. University departments may focus on research, but without undergraduates, research will not flourish.

Continuous evaluation of students is essential. Continuous evaluation of the faculty is needed too. Bodies like NAAC need to become independent to ensure strict evaluation of institutions.

MOOCS and Swayam cannot be a substitute for classroom teaching. They can supplement. If the availability of quality material is the key factor, MIT courses available online should have raised the standards across the globe. NPTEL could have raised the standards across the country. But that did not happen. Therefore, there is a need to ensure *quality* in every aspect of higher education.

Academic institutes are not government departments. They need to procure things and make things for effective teaching and useful research in a time bound manner. Many institutions receive funds, but they cannot make use of them because of the archaic procedures. Purchase procedures need to be simplified.

In a letter of August 19, 1943, Homi Bhabha wrote to J. R. D. Tata:

“The four years I have spent since my return from Cambridge have convinced me that the lack of proper conditions and intelligent financial support hampers the development of science in India at the pace which the talent in the country would warrant.” (Ref. Homi Bhabha as Artist, Ed. J. Bhabha, A Marg Publication, Nov. 1968, p. 37.)

Unfortunately, 75 years later, the situation remains the same.

We as a Nation simply cannot afford to remain the same for the next 75 years.
PERSPECTIVE

On the History, Politics and Science of Invasion Ecology

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Abstract

The socio-political influence on conservation science has always been contested. One such arena, which has aroused much interest, is of biological invasions. Owing to the inherent paradoxes and dilemmas in defining geographies and impacts, invasion ecology was criticized for being value-driven. The present study explores value-judgements in the evolution of invasion ecology, by reviewing the historical and modern opinions that identified species with their geographic origin or perceived impacts. We found ‘weediness’ to be the primitive term that identified species as inherently ‘bad’ and was rooted in the biblical thoughts of the Dark Age. Western enlightenment and oriental connectivity questioned such claim of species being inherently ‘bad’. Particularly, naturalist and geological expeditions after the 15\textsuperscript{th} century observed that the species that were transferred out of their range, induce negative impacts on the native ecosystem. We found this phenomenon politicized during the late 19\textsuperscript{th} and 20\textsuperscript{th} century, where species were identified with political boundaries, leading to malpractices of ‘exotic introduction’ and extreme ‘bio-nativism’. ‘Biological invasion’ was a scientific term of the 1950s, but the post-World War society perceived this ‘invasion’ with its martial influence. In the subsequent years, a quantitative and technological revolution in long-term ecological monitoring challenged the normative way of perceiving an ecosystem equilibrium or identifying changes brought to it by an invasive species. With the current science-values interface in the subject, we conclude that value-judgements about managing invasive species can help achieve conservation goals; however, its influence on the conceptualization of ecology can distort the scientific premise and should be avoided.
Introduction

Biological invasion is declared as the second most pervasive threat to biodiversity after habitat destruction (Sala et al. 2000). It is perceived as a threat to global biodiversity, agriculture and human health, and has hence attracted attention from diverse sectors (Pimentel et al. 2001; McGeoch et al. 2010). Defining an invasive species thus becomes pertinent for categorizing a species or taking any action against it. Popularly, an invasive species is defined as a widespread non-native species that has a negative impact on a native ecosystem. Owing to subjective terms like ‘non-native’ and ‘negative’ in the definition, invasion ecology has been criticized for its ambiguous nature (Peters 1991). Although these terms refer to biogeography and effect on non-human systems, their rationalization is influenced by human perceptions (Richardson et al. 2000). When a term that explains a phenomenon is influenced by human perceptions, it can overtake the rational understanding; and in extreme cases, can influence the conceptualization of a value-laden science like Ecology (Pyšek 1995; Richardson et al. 2000). For example, interpretation of invasion-related terms has perpetually produced metaphors like ‘alien’, ‘noxious’, and ‘exotic’ that carry an innate sense of wrongness and are extensively used in ecology (Chew and Laubichler 2003). Though studies have argued that such innate wrongness helps to manage the ill-effects caused by an invasive species; it can influence science and societal opinions about the environment. Cognitive linguists have inferred that a metaphor is not just a matter of words but also triggers the intended thought process, with the immediate comparative perception of facts (Lakoff and Johnson 1999).

As a result, scholars tried to make a value-neutral definition (e.g., Colautti and MacIsaac 2004) of an invasive species by trying to eliminate the human perception. However, owing to its popularity, value-driven metaphors and adjectives are retained in invasion ecology (MacIsaac et al. 2011). Different opinions of scholars regarding the identity of invasive species have divided the academicians into two visible groups, one proclaiming the value-neutrality of invasion science (Richardson et al. 2000; Holle and Simberloff 2005; Richardson and Ricciardi 2013) and another questioning the necessity of value-neutrality (Brown and Sax 2004; Davis et al. 2011; Schlaepfer et al. 2011). These extreme opinions highlight the importance of a question that the subject must raise: how strong is the science-value interface in invasion ecology and why? There have been numerous attempts to rationalize the terminologies associated with invasion ecology and biology (Blackburn et al. 2011; Jeschke et al. 2014). In fact, a few scholars argue that limiting or standardizing the terminologies can impede the development of the field of invasion ecology in different sections of society (Carlton 2002; Hodges 2008). The nature and reason of this argument polarity maybe explained by the science-value interface that has influenced the present-day conservation philosophy (Proctor 2001).

Since the notable mention of invasive species by the 19th century scientists, including Alphonse De Candolle, Charles Lyell and Charles Darwin (Darwin 1859), though not using the
same term, there have been efforts to rationalize the definition of geographies and effects on non-human systems. Conceptualization of these geographies and non-human systems, in fact, traces back to the belief system before modern science, with its roots in the enlightenment era, mercantilism, Renaissance, middle ages and the historical agrarian societies. It is the idea of ‘otherness’ that has persisted in each of these identities. The rationale behind such identities is uncertain because issues like these are examined from a constructivist perspective and are, therefore, vulnerable to personal bias (Warren 2007). Recently, due to the influence of these metaphors on conceptualisation in ecology (Davis 2009), invasion ecology has been seen in the larger social milieu of values and politics and the ‘wrongness’ or the ‘rightness’ of biological invasion has been vehemently debated.

It is beyond the scope of the present study to review all these studies. The present study explores the influence of societal value in the development of the concept of invasion ecology. Resisting the temptation to accept invasion ecology as a value-neutral science, this article reviews multiple narratives about the epistemology of biological invasions and highlights the necessity of inter-disciplinary philosophies in the subject.

**Weed and Weediness**

The earliest known concept of invasive species was in regarding plants that affected food resources of primitive human societies as weeds. Weeds and weediness are two ideas that have been constructed since the start of agriculture (Clayton 2003). With the advent of agriculture, the people-nature relationship changed. Any species that damaged cultivable ‘good species’ were identified as ‘bad species’ (White 1975). It was not until the biblical ages that weediness was used as a metaphor for representing anything evil and ‘unnatural’. Genesis (3:18) states Adam to be cursed with weeds (Speiser 1964), suggesting weediness to be equivalent to something evil (e.g. “The one who sowed the good seed is the son of man. The weeds are the sons of the evil one, and the enemy who sows them is the devil.” Matthew 13:33). Because of biblical supremacy, contemporary scholars raised concern for the lost innocence by condemning the ‘unnatural’ weeds as its cause. This influence always persisted with the term and was even referred by Shakespeare, a scholar of Renaissance Europe (“tis (world) an unweeded Garden...” Hamlet 1.2.6).

The theological overtone of unnaturalness in weeds was questioned by different philosophers (e.g. Heraclitus, Zeno of Citium, and Plutarch). Such ideas challenged the dichotomy of ‘natural’ and ‘unnatural’ since historic times. These voices were heard with the fall in biblical supremacy. But the visible arguments were due to the growing global connectivity of European scholars during the Renaissance, particularly with the eco-centric oriental societies, who influenced the redefinition of human-nature relation (Kelly 2012). The scholars during the Enlightenment era found otherness of weeds to be an outcome of human artifice (King 1957). For example, in the 18th century, botanists argued that weeds were not the cause, but rather, an effect of soil impoverishment (McDonald 1941). Many post-Renaissance scholars, including Wolfgang Goethe and Russell Lowell, romanticized weeds as ‘wilderness that rebelled against
human regulation’ (Clayton 2003). However, the majority of society was still driven by biblical supremacy that treated few species as innately evil and supported the dominance of what they considered as good species.

Exotic Introduction

Scholars influenced by the idea of European supremacy over others took the advantage of biblical references. For example, Sir Matthew Hale (1667), an English barrister, stated that man is superior to nature and hence must have control to change it (influenced by “Thou hast given him dominion over the works of thy hands; thou hast put all things under his feet” Psalm 8:6) (Clayton 2003). Similarly, Raynal (1713–1796), a French writer, believed that modifying wild nature to a garden was what distinguished civilized Europeans from uncivilised Indians (Gilderson 1996). Nevertheless, with the growth of the positivist movement in Europe, science was advocated for any political decision and was reflected by the arguments of scholars advocating species introductions. For example, Walter Buller, a 19th century naturalist from New Zealand, invoked Darwinism for the displacement of native flora and fauna (including people) by superior European species (Clayton 2003). This attitude of ‘European gardens better than wilderness’ was further backed by the vast improvement in navigation technique and diversity of available modification tools, which helped in transferring the species across the globe and modifying the native biota for economic and political purposes. Amidst the positivist movement, using science for justifying species transfer during the imperial era was thus biblical rooted and was enhanced by capitalist mercantilism and the navigation technology (Beghin and Potier 1997; Hulme 2009).

The transfer of crop plants out of their native areas was an important step in world history, as it facilitated the expansion of societies and empires (Peretti 1998). Most of the non-European societies, particularly Oriental and native Americans were constrained to using and breeding the available species in their area (DiZerega 1996; Kalland and Persoon 1998). However, colonial rule tried to modify the new countries by introducing exotic species, to make the ambience depict their homeland (e.g. introduction of oak, pheasants and rabbits in New Zealand (Wells 2006)) and for economic resources (e.g. introductions of Prosopis juliflora in South Africa (Bennett and Kruger 2013)). Perception of native people to such introductions was varied. People fascinated with the imperial lifestyle tried to accept the changes. Those who revolted against the rule led to the movement of conserving the native values and biota. Hence, ‘exotic’ was used both as a metaphor for appreciating a unique difference, as well as for criticizing an alien entity.

Nativism

Few of the introduced species escaped in the wild, spreading at an alarming and outcompeting the native cultivable and natural species. As a response to this damage, farmers and forest managers started removing such species. For example, Noxious Weeds Act (1900) was
established in New Zealand to eradicate harmful introduced species (Chapin et al. 2010); and Lantana camara (introduced species) management was initiated (1912) in parts of India (Bhagwat et al. 2012). An extreme version of this idea was to remove any entity that didn’t belong to the political extent of a particular society; an idea that led to biotic nativism. ‘Native’, before the 19th century, meant anything that was not a direct output of human artifice (Chew and Hamilton 2011). It was later related to the purism of landscape, and such purism was perceived to be free from any foreign invasions. As species were segregated based on the political boundaries and the human race in it, biological nativism was the historical outcome of apartheid cultures. For example, in pre-World War II Germany, strict biological nativism was supported by Nazism. Ideologically and ecologically, the Nazis attempted to purify their nation and nature, by eliminating people and biota that were supposedly non-native (Peretti 1998). For example, Reinhold Tuxen, head of the Reich Central Office for Vegetation Mapping, announced a fight against the ‘Mongolian invader’ Impatiens parviflora. Such decisions converted the wilderness into ‘natural gardens’, as all the ecological selections were controlled and manipulated by human interventions (Pollan 1994).

Scholars suggest that the emergence of biological nativism could also be a product of newly emerged, democratic, less-developed countries, who suffered due to (political) invasions during the World War II (Peretti 1998; Nunez and Pauchard 2010). The approach adopted by such countries usually relies on eradicating non-native species based on political boundaries. Not surprisingly, the Leopold Report (1963), a scientific document to manage national parks in the United States of America, stated that management should aim to protect and recreate native nature that was present before invasion and degradation by the first white man and biota brought by them (Hecht and Cockburn 2010). Such perspectives were based on a myth of an idealized primitive society living in harmony with the environment (Katz 2014).

Although environmental purism is not inherently racist, there are compelling arguments that nativist purism is undesirable in all spheres-political, cultural and ecological (Peretti 1998). Species ranges and extents are driven by how far they can disperse and how far back in time they did so; political boundaries are proximate, ever-changing and artificial and do not match up with the time scales at which species ranges expand. Hence, political boundaries should not be considered for assigning species with their identities. All the same, contemporary attempts to preserve differing cultures and small-town community life by limiting foreign influence need not be racist or xenophobic, but rather, an attempt to preserve the spectacular diversity on earth (Hettinger 2001). However, if human modification of ecosystems is left unchecked for natural selection to happen, it will lead to the completely human-controlled ecosystems (Katz 2014).

Biological Invasion

The experience of few species being harmful to the ecosystem, their geographic identities, need to control their impacts and emerging quantitative ecology of the 20th century led to the rationalization of the concept of biological invasions. The species out of their geographies were recorded by naturalists of the 18th and 19th century including Pehr Kalm, Alexander
Humboldt and many others (Davis 2009; Chew 2011). Charles Darwin considered this phenomenon when he observed that non-native species could threaten native species on islands (Darwin 1859; Richardson and Pyšek 2008). As described by the previous study (Davis 2009), the influence of geographies on species was also motivated by Wallace’s six distinct bioregions of earth that inspired the contemporary biogeographers to explore the biology of species outside their bioregion. To geographers and voyagers of the 19th century, this was all about human introductions that affected the species of distinct geographies. One of the first few published records of invasive species, was for species (native or non-native) that burgeoned, resulting in the rarity of other species (Brandis 1891). Subsequently, ecological knowledge accumulated as a product of geological and naturalists’ expeditions. Early ecologists observed the ecological difference brought by the species that got out of its native area (Spalding 1909; Thomson 1922; Egler 1942). The impacts that these species can have on the introduced area started getting the attention, particularly with non-native plants (Campbell 1926).

It was not until the 1950s that the subject gained ground in the scientific community. Marston Bates 1956, in his chapter, ‘Man as an agent in the spread of organisms’, reported that the species which spread with human movement can become ‘Neobiota’ in different regions. Another contribution was by Charles Elton (popularly known as the father of invasion biology) in ‘The Ecology of Invasions by Animals and Plants’ (1958). Elton flagged the concern on biological invasions using radio broadcast and used general language to convey the seriousness of the topic. Unlike many other scientific publications by Elton, the starting paragraph of his book ‘The Ecology of Invasions by Animals and Plants’ dramatically claimed “It is not just nuclear bombs and war that threatens us. There are other sorts of explosions, and this book is about ecological explosions” (Elton 1958). Based on the ecological observations for more than a decade, Elton warned that the loss of biodiversity due to invasive species would be so severe that “Instead of six continental realms of life, there will only be one world…” (Elton 1958). Scholars criticized Elton’s idea as a product of his martial mindset and language developed by the World War society (Chew 2006). However, Elton’s work since the 1930s indicates that his monograph was the output of long-term ecological observations that lead to the concept of biological invasion in 1958 (Kitching 2011). Although Elton’s idea was not influenced by the post-war martial mindset, the society that was habituated with everyday war news could have perceived these martial metaphors literally. And hence, out of two contemporary metaphors of ‘neobiota’ and ‘biological invasion,’ it was only the latter that eventually became the highest cited term (Richardson and Pyšek 2008; MacIsaac et al 2011).

Modern Invasion Ecology

Modern invasion ecology that constituted itself somewhere in the 1980s, owes its presence to the advancement in quantitative ecology (Davis 2006). The global awareness for biological invasions was reflected in the SCOPE program (Macdonald and Jarman 1984) that resulted in an exponential increase in quantitative data about the spread and effects of biological invasions (Richardson and Pyšek 2008). Association of the impacts with ecosystem services and biological extinctions enabled the subject to gain strength for raising funds and carrying long-term
research. The post-1980 rise in scientific publication and citations on biological invasions symbolizes a modern rationalization of the subject (Pyšek 1995). As evident from the adjective ‘modern’, the new version of invasion ecology was based on induction (ecological surveys, lab experiments, etc.) and deduction through statistical hypothesis testing. But the ultimate objective of biodiversity management was to maintain the ‘balance of nature’ by managing invasions. Definition of the geographies and ‘negativity’ associated with the identified species is only partially addressed by such modern approaches. Thus, the workable modern definition for an invasive species was widespread non-native species whose introduction is mainly attributed to humans and which negatively impact the ecological integrity (Colautti and MacIsaac 2004). The meaning of ‘non-native’, ‘human-induced’ and ‘negative impact’ are left to interpretation by the scholars and the stage of invasion in the ecosystem.

In the modern definition of biological invasion, anthropogenic activity (Hulme 2009) is popularly considered responsible for introducing a species out of its evolutionary range, where it might turn invasive due to a release from controlling agents (competitors, predators and disease). Such assumptions suffer from ecological limitations as one cannot be definitive about the evolutionary history, or about the conservatism of this evolutionary niche of a species. Species’ distributions are dynamic; each species originated somewhere, had subsequent changes in its life histories that has resulted in its current distribution and will determine further speciation within the geographic barriers (Walther et al. 2002). With increased human transport available, humans are spreading many species out of the geographic barrier, will all these species become invasive? There have been evidences suggesting that distinct geographic origin of a species cannot be the only reason for its invasiveness elsewhere (Davis et al. 2011; Hassan and Ricciardi 2014). Hence, the duration for which a species be present in a particular location to be classified as native is more of a philosophical issue (Westman 1990) and then an ecological one. The second criterion of ‘negative’ impacts was developed keeping in mind that not all human-induced non-native species turnout to be harmful. According to this criterion, invasive species are not integrated into the ecological community but are the ones that degrade it. Paradoxically, recent studies show that natural communities are dynamic and hence, constantly prone to change (Lavergne et al. 2010). Moreover, scholars have been challenged with providing a principled distinction between harming a natural system and changing it (Gunn and Throop 2002). When the harm is to a non-human system, the justification for negative impact is complex, and scholars have recently proposed to incorporate human-values in the framework of defining negativity of impacts (Jeschke et al. 2014). Biological invasion is a special case where all the criteria are the same, except that it enforces immediate changes on the ecosystem, which in an ideal evolutionary time would give equal opportunity to the native species to respond. These imminent changes are manifested into the localized extinction of native species, loss in functional diversity and gradual homogenization of the global biota (McGeoch et al. 2010).

Further, as climate change unfolds, species will change their current distributions to survive (Peterson et al. 2002; Mungi et al. 2018). Will such species then be considered as invasive? It is inevitable that differential changes in any community will lead to the introduction of hitherto unknown species and can even result in them becoming abundant. If we want the natural processes to occur without human intervention, then the ecosystems will be invaded. And if we intervene, the processes will be no longer ‘human-free’; this alarms the onset of
Anthropocene (Crutzen 2006; Steffen et al. 2007). The recent culture in conservation science that denotes a native ecosystem as a stable equilibrium and invasive species as something that disrupts that equilibrium is thus, no longer tenable. With the fall of the Clementsian concept of climax in modern ecology, thoughts began to appear that challenged balance-of-nature paradigms regarding ecosystems. Scholars highlighted that ‘species move freely on all geographical scales’ (Hengeveld 1989). Such thoughts that challenged the ecological constructions of species, communities, and nativity, were very outcome of postmodern science (White 1998; Warren 2007).


designed to organize (Lyotard 1984) is questioning the ‘balance of nature’ and perceiving it as multiple states based on chaotic processes (White 1998). Postmodernity, as a state of society, might be yet debated but, increased references of chaotic processes in ecology (Evans et al. 2013) and the new paradigms of multiple stable states (Fukami and Nakajima 2011) allude to a common reference of postmodern thoughts. Ecosystems states can be defined in multiple ways and that complicates the utility of this concept. What state – structural or functional – must one prioritize is still a deeply subjective choice. An ecosystem is now perceived as a dynamic response to the changes in the environment, and a complex interaction explanation of which is beyond the scope of present study but can be found elsewhere (Scheffer and Carpenter 2003; Hobbs and Norton 2004). This criterion does not weigh the geographic origin of a species or negativity of its impacts as important. The first important factor is the potential regime shift in a non-ecological time and second, the anthropogenic base of such shifts. The alternate stable state is a product of human manipulation of the ecosystem, in an era of biodiversity crises due to anthropogenic influence, and thus it induces concern. Secondly, biological invasions claim to accelerate biological extinctions and economic loss (e.g. loss of US$ 314 billion per year for six nations (Pimentel et al. 2011)), and hence could be perceived as a risk (Burgman 2005). Hence, accounting human as a causal agent within a system, and not an external entity, serves the purpose of conservation. However, the potential alternate stable state poses an interesting conundrum for managerial action as removing an invader from the new regime of the ecosystem can disturb the newly established ecological networks and processes. This loss of interaction could further move the system into other chaotic states (Hughes et al. 2013). Reverting back the ecosystem to its pre-invasion state, which in itself is subjective, needs control on all micro-parameters of the ecosystem. Moreover, waiting for an ecosystem to cross the existing regime and then reverting it back consumes resources with uncertain ecological gain. The way science can help is by providing early warning signals of ecological regime shift by biological invasions, so that strategies to resist it or adapt to it, could be timely availed. This needs continuous monitoring at an optimal scale and observing any indicators of such abrupt shifts, which is yet a challenging science.

The contemporary conservation strategies propose restoration of lost ecological regimes rather than the only removal of invasive species. Owing to small sizes of protected areas and
human influence on its ecology, the probability of ecosystem reverting back to its original regimes on its own is minuscule. Although humans would regulate transformation to such a system, thereby making it anthropogenic selection; it would minimize the relative damage caused to the biodiversity. The current postmodernist views, alluding to their placement of human as a part of nature will support interventions in such cases (Robertson and Hull 2001) but should be freed from the xenophobic base. There is an urgent need to modify certain thoughts to compliment scientific decision in dealing with such conservation strategies. Many conservation biologists emphasize the importance and pervasiveness of species migration while maintaining a nativist ideology (Peretti 1998). This clash, many a time, has resulted in deactivating the management of some harmful invasions, while sometimes having resulted in the removal of native species (Sagoff 2000) and has also ended up terming threatened species as exotic and alien (e.g. Thapar 2013). Secondly, conservationists often target species that have visibly altered the landscape to an extent that adaptation to the change is costlier than removing the species. Such dissonance could be overcome by multi-disciplinary studies that have already been demanded (Larson et al 2011).

It is a time where, scholars from ecology, sociology and quantitative science come together to address the conceptualization and actions regarding biological invasions. Multi-disciplinary initiatives are showing success in using value-judgements without influencing the scientific premise. For example, considering opinions of the animal rights group resulted in successful control of feral pigs in Texas USA (Perry and Perry 2008), public participation for controlling invasive plants spread in Australia (Williams and West 2000). Invasion, in its entire context, is part of ecological science and not a different science in itself as indicated by few. Additionally, acknowledging socio-political and cultural values while addressing this conservation-oriented issue is crucial. Science in its positivist form is inept to solve such problems alone as “meanings cannot be measured, only understood” (Bhaskar 2005). Meaning could be multi-narratives and should not be feared; as our study demonstrates, including the contradictions in existing views, environmental conservation has always been a heterogeneous mixture of ecology, politics, sociology and culture.

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On UGC: statement by three Indian science academies

IASc, INSA and NASI
Prof. A. K. Sood,
President, Indian National Science Academy
Prof. R. Ramaswamy,
President, Indian Academy of Sciences,
Prof. A. Kakodkar,
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August 8, 2018

Hon’ble Shri Prakash Javadekar
Minister for Human Resource Development
Government of India
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Re. Suggestions of Indian Science Academies on UGC / Higher Education Commission Acts

Sir,

On June 27th, 2018, the Government of India formally declared its intention to replace the University Grants Commission (UGC) Act of 1956 by the Higher Education Commission of India (HECI) Act. The Science Academies (the Indian National Science Academy, New Delhi; the Indian Academy of Sciences, Bengaluru; and the National Academy of Sciences of India, Allahabad; Encl. 1) have carefully examined the UGC Act and the draft of the proposed HECI Act and conclude that the existing problems were not due to inadequacy of the UGC Act but have arisen due to deficiencies in its implementation. We also note that the principles leading to the HECI Act have not been clearly spelt out. Any change without due consultative process may prove detrimental to the trajectory of higher education in India.

Education in respect to its quality, its excellence and its reach to masses is cardinal to the socio-economic firmament of the country. Recognizing this paradigm, the three Science Academies pro-actively discussed various issues associated with it. Consultations across the country and views of the academic community suggest caution in replacing a reasonably functional system with a radically new one. The academies consider that appropriate corrective steps coupled with enhanced investment in funding can remove the current aberrations in the UGC system to
The proposed HECI Act leaves much to be desired in terms of its scope, appeal and implementability. A detailed analysis of the draft Act reveals that several of its components mimic the current UGC act and some others are either impractical or undesirable and their application will significantly compromise the growth of education in the coming decades.

Some major concerns are briefly mentioned below and the Academies request an opportunity to discuss these and others in more detail at any appropriate time.

1. The constitution of the proposed HECI Act has grossly insufficient representation of educationists and academics of proven credentials. It is essential that any such Commission should predominantly comprise academics of proven credentials, without any bureaucratic control. The proposed constitution of HECI will move the education of future generations from the hands of educationists to those of bureaucrats.

2. Educational systems and academic schools take years to build. Therefore, the proposal to seek performance reports on an annual basis defies comprehension. The gargantuan nature of the tasks involved in achieving a reasonable evaluation of about 1000 institutions has perhaps not been appreciated. This number is expected to increase rapidly in the years to come, which makes the idea of annual reviews, a Mission Impossible.

3. While it is easy to withdraw licenses of institutions that underperform, it is difficult to imagine the fate of thousands of students who would suffer by such actions.

4. It is not clear how the performance indices will be translated into fund allocations. The dual instruments of academic performance evaluator and financing body will be detrimental to the system.

5. The proposal to penalize the administrators of institutions under the Indian Penal Code for their failure to achieve an undefined performance level will not be conducive to an academic environment. On the other hand, a proactive policy of encouragement to the performers will be more productive.

India and its people are at critical cross roads. India's objective of providing better lives and employment to its billions and the success of enabling programs like Swatch Bharat, Swastha Bharat, Make in India, Start up India, would need the best of human resource that can be generated only through the university system, now and in real time. The proposal for HECI would imply substantive delays and confusions, which the country can ill afford at this critical juncture.
It is therefore, the considered opinion of the Academies that the existing UGC system be strengthened by ensuring that the UGC Act and the academic autonomy of higher education institutions are implemented in letter and spirit. Functional autonomy buttressed with generous and optimal funding and its timely release will facilitate administrative and regulatory procedures that would ensure excellence in education.

Further, any organizational set up in the country has to encourage the youth so that they appreciate the value of higher education for their growth. The quality of infrastructure and development of international interfaces with experts will be critical for the socio-economic agenda of the country.

Academic Institutions should not be construed as government departments but as centers of creativity, which are assured of flexibility in administration and ease in the release and use of finances in real time.

It may be appropriate here to recall the sage statements of Homi Bhabha and C.V. Raman. In a letter of Shri J. R. D. Tata on 19 August 1943, Homi Bhabha wrote

"The four years I have spent since my return from Cambridge have convinced me that the lack of proper conditions and intelligent financial support hampers the development of science in India at the pace which the talent in the country would warrant".

These words still hold true.

Nobel Laureate, Prof. C. V. Raman said in 1942,

"If you ask me what is the greatest industry of a Nation - the key industry - I have no hesitation in saying that it is the production and diffusion of knowledge. There is no nobler work for a man or an institution than to bring up a young generation in health and strength and in the vigor of intellectual and physical activity."

We also recall here a statement by R. Enarson,

"The universities are a very special place. They are fragile as truth itself is fragile. They exist by public sufferance, and it is a marvel that the public at large supports it with its dollars an institution that is independent, free-standing, openly critical of the conventional wisdom, enchanted with controversy and hospitable to those 'who think otherwise'. May it always be so" (Science 181, 897, 1973).

In conclusion, the Science Academies, jointly and, without any exception, recommend that every effort be made to retain and strengthen the UGC with full functional autonomy and with substantial augmentation of finances. This will be the only way, the Indian Education System can continue to prosper and remain competitive, internationally.
The Science Academies would be willing to work with the MHRD and provide concrete suggestions on the recalibration of the UGC system with a futuristic outlook, whenever called upon.

With regards,

A. Kakodkar
President, NASI

R. Ramaswamy
President, IASc

A. K. Sood
President, INSA

Cc:
Prof. K. Vijayaraghavan, FRS
Principal Scientific Advisor,
Government of India
The Indian Academies

The Indian National Science Academy (INSA), Indian Academy of Sciences (IASSc) and the National Academy of Sciences of India (NASc) represent the most accomplished intellectual pool of the country with an illustrious record of substantive contribution to Indian Science. With a combined strength of over 2500 Honorary Fellows, the academies have been extensively contributing to the entire canvass of Indian science, ranging from the promotion of science and developing scientific temper; the human resource development; in developing policy paradigms and towards the broader goal of harnessing scientific knowledge for societal good.

Formed over eight decades ago, and funded by the Government of India, the three academies, work in a complimentary and synergistic mode towards providing an interface between the government, academia and the public. Thus the academies been informing and developing Policy Prescriptions (through publications and statements). Nurturing Science and Education in their broadest sense, and contributing substantively to the Quality Human Resource Development in the country through various programs.

Besides its other activities, the INSA, carries an additional role mandated to it by the Government of India, towards representing it, in all international fora. For over 5 decades INSA has been carrying this task with due diligence and through a pan-Indian consultative process, which has ensured Indian presence in the international science at a meaningful and decision making level. In the process it has developed several initiatives that help Human Resource Development in India. INSA has also played a major and a globally applauded role in developing the discipline of History of Science. Further, well researched publications of INSA like, Higher Education in Science, Health of Science in India, State of Indian Universities, Restructuring Post School Science Education, the book on Ethics in the Use of Animals for Scientific Research have provided the policy planners the perspectives from the academies.

The IASSc, besides its other activities likewise, has excelled in developing publication of Scientific Research in India and has provided a direction to quality publications from India. The Current Science published by the Current Science Association and managed by the fellows of the Academy, has an international appeal, with at least over half a million readers over the world. Subject journals published by IASSc have an international reputation with a combined subscription running into tens of thousands.

The NASI, has been carrying out yeomen service in the area of Science outreach and Education, with the objective of developing scientific enquiry and temper in the
society for cultural improvement through human knowledge. The Academy undertakes numerous “science-society” programs to ensure that science does not remain confined to laboratories.

Major joint activities of the three academies include:

1. Joint Science Education program (aimed at UG/ PG students and their mentors) with a total of 4 thousands and teachers, benefit from these programs annually.
2. Women in Science in India program, aimed at attracting and empowering a woman scientist and achieving gender equality
3. Ethical Conduct of Science in India aimed at betterment of scientific standards and moral values amongst active researchers and their mentors.

In addition, the academies have a strong synergistic and consultative process for opinions on issues of contemporary national interests and therefore most inputs to the Government are provided jointly.
Rewriting the Contract with Science

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Abstract

The social sciences stand at a critical juncture today; they have lost the capacity to intervene effectively and authoritatively in the public political discourses. Are our methodological practices responsible for this? Do we need to take a critical look at these practices and reassess them?

Keywords. Philosophy of science and social sciences; Relativism; Truth and justification; University; Democracy.

The Problem

During the 20th century, philosophers of science and social science were concerned overwhelmingly with identifying what can legitimately be called science and scientific knowledge, and, differentiating between science and other forms of learning. Indeed the distinction between science and other modes of cognition was central to the social and political imagination of the 20th century. But today we stand at the crossroads where the line separating science and non-science is becoming increasingly blurred. Whether it is a case of treating an illness or accepting what counts as evidence on the basis of which we can claim to
know the truth (at least in a weak sense), in each case, different forms of knowing and learning are jostling for the same space and equal recognition.

Take, for instance, the case of dengue fever: the search on Google will reveal many more entries and ‘likes’ for such remedies as eating fresh papaya leaves, drinking papaya juice, tulsi water, giloy, etc., than monitoring platelet count. One will find a few references to the latter and occasionally an advisory to consult a doctor. The same goes for other conditions, such as cardiac arrest, liver or kidney malfunction, gout, etc. On social and historical issues too we have a variety of stories and representations circulating, both about the past and the present. It is said that aeroplanes and the internet existed in ancient India; that procedure for rhinoplasty had been spelt out in ancient texts some 2000 years ago; that Rana Pratap won the battle at Haldighati, etc. In many intellectual circles, these assertions are summarily dismissed as instances of fake news or ‘invented’ facts, but even this charge does not settle the issue; it does not win the argument, and we need to ask just why that is the case.

The problem before us is a serious one and we need to confront it head-on as the ‘new’ narratives are not thriving on ignorance; they are being widely circulated and forwarded by the educated middle class. The reproduction of such narratives cannot also be explained in terms of political power and ideology. While the latter may play a role, as social scientists we need to consider just why has the ground of discussion and debate changed so swiftly? Why has space previously occupied by specialists, historians, social scientists and trained medical practitioners, been ceded to parties and communities? If matters that were earlier settled in institutions of higher education are now being concluded in the political arena, then the fault must also lie with us in the academia. We must scrutinize our methodological and disciplinary practices to understand why power and politics rather than scientific exploration and explanation count for more even in the imagination of the middle class.

This paper tries to reflect on this issue. Instead of focusing on what politicians do, or how power manifests itself, it turns the gaze inwards to scrutinize our own methodological orientation and the crisis it has created. The predicament we face today is, to an extent, one of our own making; only when we recognize this, can we begin to address the challenges that confront us in society and in higher education.

The next few pages argue that in the second half of the 20th century there was a consensus of sorts on what should rightfully receive the status of knowledge (as opposed to other kinds of experiences and opinions). There was an accompanying agreement on what could legitimately be accepted and incorporated in textbooks; and what protocols were essential to justify a claim. Different disciplines (in the natural and the social sciences) had established methodological norms that had to be followed. However this consensus has gradually eroded and ‘solidarities’, political and ideological, have displaced acceptable modes of justification. In fact, the question of truth and justification has been surgically removed from the discourse. What we have, as a consequence, are competing assertions vying for attention and public space but no agreed-upon grounds for assessing them. The consequences of this are manifold and visible in different ways. Earlier, disciplines, like astrology, yoga, naturopathy were placed in forums outside the institutions of higher education. Today they
are knocking on the doors of the University, asking not only to be admitted but to be treated at par with, and certainly not subordinate to, the designated sciences.

Voices in support of such claims may have become more shrill and prominent today but it would be naïve to think that the change we are witnessing is on account of an ideological shift – a change in the preferences of a group or party. While the reception and public space that these views are getting may be explained in terms of shifts in ideological and political power in our society, this trend is visible in varying degrees in many other parts of the world. We must, therefore, take these developments, and the challenges they present, seriously and ask – i) how did we end up in the situation? Why has science (as it was understood in the 20th century) lost its privileged position and legitimacy? ii) How should we now think of knowledge, truth and science? And, what methodological protocols might be put in place, particularly while considering the claims of different fields and practices that find a place in institutions of higher learning? There is an urgent need to initiate a debate on these issues in the university as well as other public forums.

Philosophers of science have been dealing with questions of this kind for some time but most of those debates take the natural sciences as the point of reference. That is, they discuss what scientists, studying the natural sciences, do; they examine scientific theories (how they are arrived at and defended), the role of the scientist (individually and collectively) and the working of the laboratory. Their analyses hold important clues for the social sciences and the challenges they face but these need to be drawn out, reflected upon and interpreted in ways that address the concerns of the social scientists.

Given the current debates on epistemological issues, my repeated invocation of truth and science may appear problematic to many. In fact, after the interpretive turn in the social sciences and the tilt towards constructionism, social scientists are reluctant to use these terms and at times it seems that these concepts belong to an era gone by. Yet, in the current context, it is essential to bring these concepts back into our discussion with the awareness that in the post-enlightenment world, science cannot be equated with, or conceived as, a form of technocratic, instrumental rationality that describes the world as it is in neutral and moral terms. The task before us is to re-signify the idea of science and confront the challenge posed by relativism in the social sciences. Without it, both democracy and the liberal university may be under siege.

As was noted earlier on, I am concerned primarily with the social sciences. However, all through the 20th century, the discourse of the social sciences was to a considerable extent shaped by the debates in the philosophy of science. In fact, in the early part of the last century, the social scientists saw the natural sciences as the model or the prototype of what science is. Subsequent reflections and reconsiderations of the concept of science in the natural sciences had a profound influence on the thinking of these disciplines and it produced scepticism about achieving objectivity, truth or knowledge in the social sciences. Those who resisted the imposition of an external model on the social sciences and placed the category of meaning at the core of the social sciences too moved in a similar direction and gradually abandoned the quest for objectivity. The internal critiques of the sciences slipped gently into some form of relativism. The next section, therefore, turns to these internal critiques to understand how
ideas of knowledge and truth changed dramatically over the last fifty years. Briefly exploring how these issues are addressed in the natural sciences, the paper turns to the social sciences to reclaim the lost ground and brings back the question of justification into the discussions of the social sciences and the practices of the University.

The Legacy of Internal Critiques

The publication of The Structure of Scientific Revolutions by Thomas Kuhn in 1962 changed the discourse of science in a very significant way. Up until then, most philosophers of social sciences (and to a considerable extent, philosophers of science), operated with what might be called the common sense idea of science. They presupposed the existence of an external reality independent of the knower and claimed that science offers a picture of that objective reality. As such, they assumed a distinction between subject and object, knower and known, and believed that scientists (natural and social) provide (or at least seek to provide) an accurate description of the external world, and explain why a certain phenomenon occurs at a given time. The actual narrative of the philosophy of science was obviously more complex than this. Even the Vienna Circle moved away from the simple picture theory, advanced by Wittgenstein in Tractatus. Moritz Schlick and others recognized that knowledge involved a triadic relationship between subject, object and language. Since observations were presented in and through language, there was no pure observation or language-independent observation. One had, therefore, to identify what is ‘cognitively meaningful’; members of the Vienna circle also acknowledged the presence of concepts and theoretical terms in scientific theory. In fact, as language was the medium of representation, some even made an effort to create a more precise, physicalist language to ensure that words/concepts convey the same meaning to others (Carnap 1931 in Alston & G. Nakhnikian 1963).

Logical positivists thus added a new layer of meaning to the existing conception of science. They altered the idea of objectivity embedded in the earlier understanding but did not relinquish the search for truth, or universal truth. Realizing that the presence of the subject could not be completely erased, they set about minimizing the space for subjectivity in scientific knowledge. At the end of the day, they continued to claim that scientific theories are, and must be, verifiable, and reducible to ‘observation statements’ or ‘protocol sentences’ (see Uebel 2007).

However, the internal critiques of science did not stop here. While logical positivists pointed to the absence of language-independent observation, later philosophers interrogated and redefined the relationship between observation and science. Hanson, Achinstein, to name a few, argued that scientific theories contained concepts that were not directly reducible to objects given in observation. While some concepts, such as, water, salt, may point to things that have a direct equivalent in the world, scientists use concepts like pressure, current, gravity, that do not refer to any directly observable object. These concepts were only indirectly observable: that is, we can only observe them with some instrument; one could specify operations which, if performed, would yield a certain observable effect. For instance,
one could say that if the circuit is completed in the following way the bulb will light up, thereby indicating that the current is passing through at this time. Here too science still focused on that which was given in observation albeit one could include concepts that could be translated into effects/phenomena that can be observed.

A stronger challenge came from the argument that observation involves naming something as X. To put it another way, philosophers of science nuanced the idea of observation further to suggest that – a) observation is not to be reduced to seeing; and b) seeing involves interpretation. In the first instance, it was argued that observation, that is considered to be the building block of science, is something more complex and varied than seeing an object. Often we place within the ambit of observed/observable things that we infer from the exercise of other sensory perceptions. For instance, we see clouds of smoke in a distance and infer that there is a fire there, even though we have not directly seen the flames. Similarly, on hearing the sound of dried leaves being crushed, we claim to know that a person was running across the field. Both kinds of assertions are accorded the status of observation statements. Hence, what it means to observe is a far more complex activity than we realize; and science is not to be reduced to things that are, or can be, seen.

Even more importantly, theorists of science maintained that a theory/conceptual schema is involved in the act of observation itself. Seeing involves identifying and naming the object. Kepler and Brahe may have the same ‘retinal impression’ or receive the same ‘stimuli’ when they observe the setting sun, but they see different things. That is, they organize these impressions differently and do not, in that sense, see the same thing (Hanson 1958 in Brown, Fauvel & Finnegan 1981). Seeing and naming are not, in this sense, two distinct activities in which the former is prior to the latter. I see an aeroplane in the sky or an eagle in the sky; I do not first see certain properties and then sit back and collate them together into some identifiable object that is then named. Seeing always involves naming, and this means that some conceptual schema on the basis of which we name different objects is already present in each and every observation. Since the schema is devised by the community of scientists or taken from the linguistic practices of a social community, the subject is actively present in the knowledge process.

Another line of argument brought the subject in by highlighting the place of interpretation in scientific inquiry. Karl Popper, for instance, argued that theory is involved in designing an experiment and the scientist also plays an active role in interpreting the findings of the experiment. In other words, interpretation was involved at many levels and even the establishment of so-called ‘verified facts’ is an outcome of interpretation. We could never say that a proposition has been verified fully or a conclusion tested completely. All that scientists could do was to try and falsify a hypothesis, and so long as the hypothesis is not falsified we could take it to be true (Popper 1959 & Popper 1963). But here again, falsification was not a simple process based on pure observation. Observation of a single fact to the contrary rarely led to the rejection of the postulated claim. An existing theory (or a set of propositions) is given up
only when the scientists have a new theory with greater explanatory potential (Lakatos 1977; Popper 1959).

Thus, in many different ways, the idea that science embodies neutral and theory-independent knowledge and that scientific theories offer generalizations that are drawn from systematic observation was gradually being questioned and disputed. However, despite these different points of view, the scientific community held on to the belief that objective knowledge was possible; the idea of objectivity was redefined but a distinction was still maintained between subjective perspectives and scientific knowledge. Even when philosophers of science argued that a single evidence to the contrary may not lead to the rejection of a scientific theory they continued to affirm that ‘methodological falsification’ was possible. The scientists were willing to give up a theory and search for a new one: one that could explain these contrary occurrences. Hence, even as the ground was ceded to interpretation, the idea of science and the scientific theory was retained. In effect, this meant that explanations drawn from different modes of analysis could not be treated at par and accorded the same legitimacy.

This changed, to an extent, with Kuhn’s writings. The Structure of Scientific Revolutions offered a powerful account of the role of paradigms in scientific investigation: science was a puzzle solving activity and the puzzle a group of scientists work upon, the methods they use, and what they consider to be a solution, depends upon the paradigm they use. There was no paradigm-independent way of evaluating the process or the end result. In other words, a community of scientists (and there could be more than one community at any given time) were the ‘producers’ and ‘validators’ of knowledge (Kuhn 1970), and one could not speak of a distant objective reality against which their findings could be checked – validated or falsified. Coupled with the view that a shift from one paradigm to another could not be explained rationally (Kuhn referred to it as Gestalt switch) the Kuhnian framework left decisions about truth claims dependent upon the judgment of the scientific community.

Kuhn went on to explain that his intention was to draw attention to the role of the scientific community and not reduce science to subjective beliefs. To his critics, he clarified that scientists (more than others) can and do come to an agreement and share goals and commitments. Hence, the decisions of the scientific community were not completely arbitrary and subjective, but his analysis postponed, almost indefinitely, the question of truth. This decoupling of science (and scientific inquiry) from the quest for truth fundamentally changed the discourse of not just the sciences but also the social sciences. In anything, it had a deeper impact on the latter. The sciences could invoke a technical criterion; besides, as the sciences

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[2] Lakatos made a distinction between naïve and methodological falsification: it was naïve to assume that a single observation could falsify a theory. Most of the time scientists try to explain why we did not observe what had been predicted. “They solve (or dissolve the apparent anomalies by auxiliary hypotheses or other ‘conventional strategems’)” (Lakatos 1970:105). A theory, as Popper himself clarified later, stands rejected or falsified only when we find a new theory with increased empirical content.

[3] The scientific community share a disciplinary matrix (a set of beliefs, values, conceptual vocabulary and techniques) and a set of exemplars (examples of puzzle solving).

[4] Reconstruction of the original context (in which the author lived) raised several methodological issues: for instance, how does one reconstruct the life of the other? Does such reconstruction require empathy with the other? How does one move between the life of the author (his/her biography) and the history of that period? All such methodological issues became irrelevant as the reader gained more autonomy over the text and the author became steadily irrelevant.
were marked by periods of ‘normal science’ where one paradigm dominates, there was a higher degree of agreement among the members of the scientific community on what is acceptable and designated as true, at least temporarily. The social sciences, where we have competing interests, paradigm-dependent knowledge not only ruled out the possibility of consensus, it suggested (or was interpreted to suggest) that different readings were equally valid and none could be justified to those outside the paradigm.

Kuhn had focused on the role of the subject; he did not question the existence of an external substance or objects; later—day philosophers, like Bruno Latour, did just that. If earlier theories brought the subject into the epistemological process, Latour destabilized the idea of the substance/object. The object was no longer seen as a passive entity, observed by and responding to the conditions created by the scientists, rather it was seen as an active entity, changing with the context/state of affairs and not reducible to a set of generalized properties (Latour 2005). The properties that were associated with an object, even a natural object, were those that emerged through institutionalized practices of the scientists. This idea – that the object is constructed, or ‘compositional’- dismantled every aspect of the realist paradigm, and after this, it was even more difficult to speak of truth-claims. If there was no object with fixed generalizable properties, then what kind of truth claim could we have? This changed our conception of science and, coupled with the idea of paradigm driven knowledge, it tended to pull the social sciences further down the abyss of relativism.

Social Critiques of Science

There was yet another line of attack, and this came from the sociologists of science. Even those who did not give up the idea of checking theories against reality, however theory-laden that might be, spoke of power equations within the scientific establishment and the effect this has in the laboratory, in the shaping of research agendas and decisions taken by the scientific community (Barnes 1972). Others pointed to the manner in which science privileged the specialist and the knowledge of the experts over all other forms of experience and knowledge. Driven primarily by the technical interest – namely, control over the object - science was accused of delegitimizing local knowledges, which communities of practitioners (for instance, peasants, tribal populations) had achieved through generations of practice (see, for instance, Nandy 1990). Science, in this debate, came to be associated with value-less (rather than value free) knowledge that was open to appropriation for different purposes while local and indigenous knowledge was seen as being holistic, sensitive to the object it was dealing with (for instance, nature), and mindful of other species and future generations. If the former argument pointed to the operation of power in science/scientific communities, the latter criticized the power exercised by the knowledge that was labelled as science. Once again, for different reasons, science could no longer claim to offer knowledge that was free of prejudices and backed by indubitable proof. In fact, the critic’s privileged the lived experiences of communities the wisdom embodied in them. From their perspective, ways of life that had existed and survived over a period of time must have something inherently valuable in them.
Collectively, these critiques – some arising from within the scientific community and those studying the working of the scientific community/ies – and others that came from social scientists looking from the outside at the effects of science and scientific rationality, dislodged the privileged position that science enjoyed in much of the 20th century. They also blurred the distinction between science and non-science. It seemed that all forms of inquiry were beset with the same difficulties and none could claim to arrive at the truth. There was an accompanying suggestion: namely, insights that had previously been dismissed as untruths by the scientific community had some value and this needed to be recognized and accommodated in the institutions of learning. Indeed, some analysts went so far as to say that they must be placed alongside, and to an extent even favoured, over science.

These social critiques of science had a profound impact on the social sciences as the idea of truth was already under siege from other schools of thought -from post-positivist to the historicist tradition. The former (as was observed in the last section) gave more importance to theory and interpretation in the process of knowing. Although they did not deny the existence of an external world (independent of the knower) they maintained that we know the world only through the categories we employ and the latter may change from one theory to another. Following upon this, it could be (and indeed was) argued that what social scientists present as knowledge is constructed (rather than given), and accorded certain relevance and significance on the basis of the theoretical predilections of the investigator. Multiple narratives were therefore inescapable, and one could leap forward to proclaim that there was no way of favoring one narrative over another.

The historicist tradition too moved towards a similar conclusion. In the 19th century, when philosophers emphasized the historicity of the text, the idea of objective knowledge was still retained. The reader was expected to follow certain interpretative procedures (historical and linguistic) to reconstruct the context in which the author lived, and on that basis recover the meaning of a text or what the text says, with a considerable degree of certainty. However, later on, when the focus shifted to the historicity of the reader, the situation changed dramatically, as the idea of history itself changed without much discussion. Previously, history denoted a shared ground that alters with time due to changes in material/objective and subjective conditions; but for a period, it provides a common context of experience. By this reckoning, historicity of the reader should have given us plurality of readings located in different historical contexts and by default some sameness or consensus of meaning within a historical world. However, this was not the case. In Gadamer’s framework (which shaped this debate), the individual imperceptibly became the point of reference. Instead of conceding space to different narratives arising in different historical contexts, social scientists converged their focus on a specific conjuncture. Every individual, situated as they are in different paradigms and settings, could read the text in their own way. Every reading involved, what Gadamer termed as, ‘fusion of horizons,’ but that is all that could be said. It seemed meaningless to raise questions about the adequacy of the offered explanation and
understanding (Gadamer 1979). As Habermas pointed out, one could no longer distinguish between understanding and ‘misunderstanding’ (see Ricoeur 1973).

Within the Gadamerian framework, a fusion of horizons held many possibilities; it could end up affirming our initial beliefs/pre-judgments or challenging them. There was no way of deciding between competing readings and Gadamer also had little space for discussions across groups of readers. Instead of being the collective ground on which we stand, history became an individualized point of location and assertion, allowing for a variety of interpretations. Those who wanted to destabilize the dominant narrative privileged the perspective of the marginalized but they too offered no basis for bringing back the idea of truth or objectivity. There was a political and ideological rationale offered, but that is about all. One could ask: from whose perspective was the narrative constructed? But in a framework where truth was considered to be a tool in the hands of the powerful and all narratives were constructs, there was no need or reason to, debate the objectivity of the narrative, let alone focus on the grounds for justifying the narrative.

It is not my intention to dwell on the debates around the question of interpretation. The only point that I want to underscore here is that the idea of truth came under attack from diverse perspectives. In the social sciences, the idea of science and truth was, for a while, displaced by interpretation but the latter gradually came to represent the mere act of reading with an open mind. It treated all practices (be it, reading a written text, or living a life or analyzing a socio-cultural organization) alike and gave freedom to the subject to shape them in accordance with her/his own preferences and prejudices. This mode of reasoning had the potential of destabilizing existing hierarchies and structures of power but it also lent legitimacy to all representations of the present and the past.

Collectively, this frame of reference in the social and cultural sciences coupled with the internal and external critiques of science have engendered the present crisis: one where the distinction between science and other kinds of learning and doing has been blurred and all narratives are seen as interpretation offered by the investigator. Hence, they vie for the same space and legitimacy, and people can choose between them depending upon their personal or ideological preferences.

Ditching Relativism, Reclaiming Science

The challenge confronting the social sciences is thus a serious one, and we need to respond to it with some urgency. The issue before us is - how to reimagine the idea of science/scientificity while abandoning the realist assumptions of enlightenment theorization. This is not an easy task but, to assure ourselves that this is not an impossible task, we can examine how

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[5] This shift went along nicely with the Kuhnian understanding that location in a paradigm matters; we could only have a shared view within a paradigm, and when more than one paradigm prevails, multiple narratives and accounts exist.

[6] The interpretive framework recognized the presence of the social in discussions of the rational, and for this reason, backed free play of interpretation. But ceding the ground to the social so completely has also prevented the social sciences from serving the critical interest.
philosophers of science have attempted to rescue critiques of realism (as well as nominalism) from relativist readings.

Philosophers of science, who were challenging the possibility of knowing the external world as it is, did not advocate or push their argument in the direction of scepticism or relativism. Often they were replacing one criterion of truth with another. Take, for instance, the work of Thomas Kuhn: in ruling out the possibility of any paradigm-independent knowledge, he set aside the correspondence theory of truth. But this did not imply that all theories and explanations were equally acceptable. He invoked logical and aesthetic criteria to explain how shifts occur from one paradigm to another.

In the Kuhnian framework, we may not be able to offer a rational criterion to explain paradigm shifts, but we can nevertheless say that the chosen paradigm offers a better account of the given reality. In determining what is better or more adequate, the issue of ´internal and external consistency´ is considered by the scientific community. Scientists assess on the basis of ´simplicity, scope, comprehensiveness´ of a theory; they consider if a theory is ´simple, self-consistent, and plausible,´ and ´compatible...with other theories currently deployed´ (1970:185). Scientists take these elements into account while assessing a theory; they invoke these criteria to persuade each other of the truth of their claims and, eventually, a consensus is reached within the scientific community about what is acceptable and adequate. In other words, even though research is guided by a paradigm and its disciplinary matrix, there is communication with others outside the paradigm and an effort is made to build a consensus about the validity of the offered claims by persuading other members of the scientific community.

Similarly, questions of justification and adequacy are not given up in Bruno Latour’s framework. In the scientific community, there is discussion about good and bad experiments, adequate and less adequate interpretation. Even if we cannot know or assume the existence of the thing-in-itself, for Latour, there remains the need for, as well as the possibility of, offering justifications. Scientists may work with specific paradigms; they may make sense of things only in terms of specific practices that define a web of relationships, but they continuously seek to persuade others through a set of justifications (Latour 2005). I have drawn on these two examples only to reiterate that rejection of the correspondence theory of truth as well as the presence of the social need not leave us with relativism. Philosophies of science have made an effort to try to re-configure the idea of science taking cognizance of the presence of the social along with the rational (see Longino 2002). The social sciences need to do the same and consider how the space conceded to constructionism and interpretation do not leave us at the precipice of relativism.

Social scientists have, however, been reluctant to move in this direction for two reasons: one, the debates within the social sciences invariably dwelt on the difference between the natural and the social sciences. If some spoke of the difference in the purpose of the two sciences, others suggested a difference of ´degree´ on account of the subject (namely, human beings rather than natural objects) they dealt with. In each case, the assumption was that the social sciences cannot, or should not, follow in the footsteps of the sciences. Two, by the end of the twentieth century, social theorists were increasingly of the view that the social sciences must serve a critical or emancipatory interest (Habermas 1972). The hard sciences served a
technical interest; hence, in these disciplines questions of truth and falsehood could be settled on the basis of technological applications and innovations engendered by a theory. The social sciences, by contrast, were expected to perform a critical purpose: i.e., push for exposing and deconstructing our prejudices. Technical and predictive certainty was therefore not enough. Critique required dismantling the prejudices of the present; one needed new ways of reading the past and the present – something that needed a shift to creative interpretation, including Nietzsche’s dictum, creative misinterpretation.

The emphasis accordingly was on new ways of reading and presenting the otherwise familiar narratives. Alternately, building on the belief that narratives were the construction of the knower, and they served certain social and political purposes, the emphasis now was on multiple and diverse interpretations (Derrida 1974). The ground ceded to the social (in particular, the presence of power) thus made questions of truth and justification insignificant, if not also modes of entrapment.

The interpretive turn in the social sciences had the potential of destabilizing the dominant narrative of our time as well as the dominant narrative in a given society. But it also left the door wide open to the construction of multiple accounts, drawing upon divergent sources. One could invoke local community knowledge for sustainable agrarian practices as well as for observing certain social practices and handing down specific accounts of events. Memory, tradition, religion and culture could be drawn upon to offer remedies for illness, an account of the past, or even for mapping culturally significant places. In other words, the silences and the gaps in history could be filled in different ways to offer divergent narratives of events and personalities. The emphasis on multivocality and the perception of such difference as desirable was thus open to a variety of uses. Philosophies of science had stressed the role of the investigator, the historian and the social scientists in the process of cognition but they did not attach a positive value to it; that is, the presence of the social posed a challenge and one had to find ways of going beyond it to reach out to other scientific communities. In the social sciences, several schools of thought, particularly the post-modernists and the post-structuralists, favored and valued the presence of diverse narratives in the hope of destabilizing the dominant structure. However, once plurality became an end in itself, and was positively weighted, it was open to diverse usages. Plurality of this kind ceased to be enabling and, as we have witnessed in our own lifetime, it has yielded endless conflict (involving clashes between holders of divergent perspectives and narratives) that can supposedly never be settled. Politics of violence has flourished in this framework.

Both pragmatism as well as the pursuit of critical interest⁷ make it imperative for us to move beyond the simple celebration of multiplicity and bring in the question of justification. Rejection of the realist paradigm may have limited the possibility of asserting claims of truth, but there is still the possibility of raising questions of justification, and this is what we need to bring back into our social and political discourses. Each discipline needs once again to debate and put in place methodological protocols for justifying what counts as evidence, the lexical ordering of different sources, and debate questions of coherence and consistency. How does one deal with an account that does not cohere with the state of material and technological development in a society? What weightage should be given to agent’s self-perception? Should we accord primacy to the way people in a given place represented themselves over later-day
representations? Methodological issues of this nature, on the basis of which we can discuss the adequacy of an account, have to be brought in more vigorously, and a consensus reached on what cannot be ignored in presenting a narrative. Even if we cannot place these protocols in the public domain where competitive politics orders the discursive, at least in the university there must be room for the latter.

At a more general level, one needs to re-signify the idea of science and reclaim it in institutions of higher education. Disciplines that identify themselves as a science, as distinct from other modes of knowing, must display three attributes: i) they should be marked by the presence of more than one paradigm. While one paradigm may be dominant at a given time, other paradigms should have existed at least over time; ii) they must be open to critique and scrutiny by the community of peers; and iii) scientists/practitioners must be ready to give up their paradigm and look for an alternative set of theoretical propositions.

Science, as a form of knowledge, requires justification and an effort to build a consensus around what is accepted as true at a given time. At the same time, it also requires a willingness to be challenged and questioned about the propositions we make. Both elements are equally important and modes of inquiry that do not meet these requirements cannot, and should not, be equated with science. For this reason, the mere presence of a paradigm of understanding or a general theory is not by itself enough; there must be, at least over time, a contest between paradigms. The absence of such public contestations places the observations and experience in that field of learning in a space outside of science.

The grounds on which certain assertions are made must also be publicly available and open to scrutiny by all. The knowledge that finds its way in educational institutions at all levels has to be open to such contestation so that others are or can be, persuaded of the adequacy (if not the validity) of the offered explanation. Paradigms are not separate islands whose life and meaning is unknown to others. They may offer different ways of perceiving and thinking but the meaning of the asserted claims is, to some extent, available to others; hence, communication and discussions can take place across paradigms. As scientists, practitioners should also be prepared to recognize, what Kuhn calls, ‘anomalies’: things that cannot be explained within one’s paradigm. If one refuses to acknowledge anomalies, one is also likely to resist questioning of the framework we are using. To arrive at knowledge that can be designated as science, one must recognize both what can be explained so far, from within our disciplinary matrix, and what requires further research and what does not fit easily within our framework. It is the recognition of the limits of one’s paradigm that allows, and pushes for, the search of alternative theories and explanations.

Disciplines and bodies of knowledge that vie for space within the university, and desire to be designated as social science, cultural science or natural science, must aspire to meet these criteria. In society, there will be other kinds of experiences and learning, including applications based on a given theory or practices that are able to read symptoms and suggest solutions, but they should occupy a separate space in society and must be treated differently from disciplines and fields of inquiry that are designated as science. It is not even necessary to affirm the superiority of one kind of knowing over another, but it is nevertheless important to
recognize the difference in these modes of inquiry and thinking; and above all, place only those that aspire to be a science within the university.

Science requires certain values: moderate scepticism, humility, willingness to be contradicted, and a willingness to admit that our conclusions and statements may not represent the truth. Sustaining these values, in turn, requires an environment in which truth is not forced upon us but emerges out of debate and discussion across different paradigms. The danger with relativism is that it nurtures only solidarities and allows power to prevail; it eclipses the need for justification and for offering good reasons for asserting certain claims. None of these can sustain either a democratic society or a liberal university. We need to rewrite the contract with science if we are to retrieve space for a meaningful engagement with the society and culture.

[1] The idea of complete testability and complete verifiability is already set aside by Carnap.

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Learning Outcome Based Science Education – Avoid ‘Old Wine in New Bottle’ Approach: Lessons from the Past

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Abstract

Our country has made progress over the decades after independence, yet a lot remains to be desired, despite periodic formulation and revision of policies in Higher Education and S&T. The commentary here deals with current changes in looking at the policies of the past and the learning-outcome-based higher education, in brief. Suggestions are made in shaping learning outcome-based UG and PG education by providing a specific example of a subject area.

Keywords. Higher Education; S&T; Policies; Learning Outcomes; Disruptive

As important as the question of ‘what expectations do society and government have from science and scientists and vice versa’, raised by Singh and Joshi (2017), is the concern that has been in circulation about the quality of teaching in colleges and universities (Bamezai 2012a, Bamezai 2012b, Lakhotia 2018). The younger generation is confused about the purpose of higher education since it has either become a process to secure certificates to financially rewarding careers or has invariably generated a human resource which remains an un- or under-utilized asset (Bamezai 2012a, Bamezai 2012b). Public opinion, incidentally, also supports this view. Divorcing, in practice, the policies of Science and Technology (S&T) from Higher Education,
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especially in relation to science education and its expected outcome, has been one of the disappointments. Also, there has been a lack of clarity and objectivity at many levels of political, educational, scientific, social and, last but not the least, bureaucratic institutions, which have been heavily draining. Barring a few rays of hope and some light at the end of the tunnel in the areas of atomic energy, space, and to some extent, dairy and agriculture, the latter with a limited futuristic vision due to the onslaught of pesticides, we have had little new knowledge generated, especially in biology. What is usually claimed is mostly a deconstruction of the known knowledge base.

The reasons for such a state in biology are buried in the history of scientist-politician tie-ups confined to some given areas (Krishna 2009), leading to selective global visibility. In addition, there has been a failure of institution builders through the 1980s and 1990s to position themselves effectively and succeed as some of their predecessors were able to. Contributions in a patchwork manner, not enough to make a sustainable difference in biology globally, and sporadic efforts only from a few within the country, have been additional factors. Unfortunately, a lot of talent remained untapped due to the personal, instead of a national, emphasis in these institutions, besides the lack of appropriate direction and path. This resulted in losing out on the contribution of almost a generation, except that of a few individuals (this is a personal view based on 40 years of work experience) (Mehrotra et al 1983). The governments and the people at the helm of affairs need to take the blame for not having created ‘a mega-science’ performing space for the subject of biology, as was possible in atomic energy and the space sciences. An interesting convergence of this multidimensional problem could be seen in the lack of clarity at the national level and the mundane reasons of human factors playing a predominant role. Therefore, it is essential to build a perspective for capitalizing on the existing talent for generating a ‘Mega-Science’ space for biology, and attempt to gear S&T policy for meeting the challenges in shaping Higher Education in the sciences and vice-versa.

No one would deny that doing good science is dependent on the quality of human resource available and the way it is nurtured, for achieving set goals, defined after a wider participation and serious brainstorming. In the prevailing ecosystem, we need to tap our existing strengths accordingly and avoid rediscovering the wheel again and again (Mehrotra et al 1983). In the area of biology, how far we succeeded in translating the policies and what they emphasized for self-reliance, sustainable and equitable development (DST 2013), is anyone’s guess. The slogans of ‘sustainable,’ ‘self-reliance’ have been verbalized in the past in several statements of the Prime Ministers and the Science and Technology Ministers (DST 2013), yet the ground realities have remained dismal. The basic minimum needs of society in terms of health requirements; avoiding waterlogging, drainage overflows, efficient and cost-effective processing of solid and electronic waste, besides the control of all kinds of pollutants of air, water, earth and the whole atmosphere, have not been attended to effectively for the past several decades. Now that we have several ‘Abhiyaans’ operational from Swachh-Bharat to Skilled and Digital India besides others (Ahuja 2018), it remains to be seen if the ground reality would change and the participation of scientists and the educated contribute to the transformation as desired. The human resource trained now on has to move beyond ‘rote-learning with a successful career of no use to the society’, to measurable learning outcomes that need to be put in place in future curricula. The knowledge thus gained has to be applied to sorting out and finding solutions to
the issues highlighted already, besides contributing to new knowledge, inventions and discoveries.

If one were to take it up as a case study to understand if higher education policies, especially in the sciences, have been designed keeping the S&T policies in perspective or vice-versa, one finds that there is apparently no such thought in circulation. In addition, in higher education, one realizes that our policies have resulted in an uneven institutional infrastructure of colleges and universities which function with different roadmaps. Thus, we have different syllabi, teaching methods, hands-on training, and different learning outcomes. Introducing uniformity, whenever and wherever tried, has obviously not worked. Added to this, the failure to keep up with the advancing knowledge base, half-hearted engagement and integration with other disciplines, and poor transfer of skill set to the students to negotiate the changing needs, have made it essential to change from incremental inputs of syllabi revisions to disruptive approaches. This approach and attitude is required to reshape the subject-specific course structures, with measurable learning outcomes. However, the exercise should not result in ‘filling old wine in new bottles’, where syllabi in different subjects are just tweaked here and there to justify the change brought in to cater to the Learning outcome based undergraduate and post-graduate education.

There have been periodic debates through the Education Policies: University Education Commission (1948); Secondary Education Commission (1952); Indian Education Commission (D. S. Kothari) (1964–66), National Policy on Education (1968); Draft National Policy on Education (1979) National Policy on Education (1986) and National Policy on Education (1992). Though wonderfully stated on paper, some of them providing extremely relevant direction for the times, they remained poorly implemented and monitored for the deliverables in terms of excellence. In a recent declaration on a process of reform of the regulatory agencies for the better administration of the higher education sector, an announcement has been made to constitute the Higher Education Commission of India (Repeal of UGC Act) 2018 to reform the regulatory framework to monitor and disburse funds to colleges and universities. This has raised issues related to the independent functioning of established organizations such as UGC, AICTE, etc., which have not been functioning as expected and desired. An opinion to oil these well and to hold them accountable, instead of replace them, has also been in the air. The fear is, the new mammoth of Higher Education Commission may in due course suffer from the same ills as the existing organizations. The solution, therefore, lies in rectifying and tightening the functioning of the existing institutions without wasting time in rediscovering the wheel. We have done the least as a country to find talent and nurture and support them, till breakthroughs emerge, save for a few exceptions that catered to small numbers. The scale that such an exercise demands and the capacity building needed for diverse requirements remain to be worked out. Most of those in the corridors of power are on a roller coaster. They need to be in deep ‘Chintan and Manan’ for needful design and execution which serves everyone alike.

There is an opportunity as the country prepares through MHRD, involving UGC as one of the organs, for free online, easily accessible education through SWAYAM. The task at hand is to develop online modules under Massive Open Online Courses (MOOCs) and Learning Outcome-Based Curriculum Framework (LOCF), for UGs and PGs in different disciplines. This process has been in place in many countries for a long time. Meetings of a core committee (in which the writer is a member) and subject-specific experts have taken place to develop a framework, with an aim to circulate the framework for debate, moderation and final adoption. I feel this is an opportune moment to bring a qualitative difference to the course structures within different subject areas of the sciences, where learning outcomes are defined precisely and evaluated objectively to match with the aspirations projected in the S&T policy of the country. The course structures need to be designed in an integrated, interdisciplinary and cross-disciplinary manner, bringing together a wide spectrum of scientific disciplines to solve complex problems and to develop new methods, concepts, and approaches. The approach, if and when adopted, to create a balance between the S&T and Higher Education policies, may generate opinions amongst teachers and students that resist the change. On the other hand, it could also be seen as an opportune moment to shape higher education by preparing human resource of relevance to the societal needs and for discoveries and innovations.

I provide here a glimpse of a subject area, as an example, to show how the purpose of S&T innovation could be encouraged by tweaking the syllabi with defined and meaningful learning outcomes. As a case study, let me pick up a subject area in biology, i.e., Zoology, common in traditional colleges and universities. In order to bring such a change in the subject in UG and PG course curricula, the intention should be to understand the subject of Zoology in the evolving biological paradigm in modern times, where, living beings need to be understood at the level of atomic interactions. The comparative systems of organisms need to be studied through a prism of integrated chemical, physical, mathematical and molecular entities to appreciate the inner workings of different organisms at the morphological, cellular, molecular, interactive and evolutionary levels. The syllabi could be shaped with a customised approach, depending on the institutional infrastructure and geographical location, yet it should cater, in principle, to the expected learning outcomes more or less uniformly. For example, in diverse geographical domains with diverse skill sets, examples illustrated in detail for teaching and hands-on exposure and fieldwork could differ by involving the study of available species across the ladder of evolution, yet the comparative biology taught should provide a uniform level of understanding of the subject. After all, the purpose should be to facilitate an understanding of the inner workings of living beings by comparing various systems within invertebrates and vertebrates i.e., from a single cell protozoan to multicellular humans, and to develop a comprehensive understanding and appreciation of the differences through ICT tools and well-designed hands-on practical exposures, along with fieldwork. In other words, if the same principle is followed for understanding different phyla through the ladder of evolution with cardinal features compared for classification involving both morphological and molecular tools, along with associated field and lab work, the final product would be better trained without being simply subjected to rote learning. Diversity in life forms needs to be understood

[2] UGC Public Notice reg.: Learning Outcome based Curriculum Framework (LOCF); UGC website-www.ugc.ac.in
by a Zoologist for their socio-economic capital, in case a student is interested in entrepreneurship, through applied aspects of Zoology; by a career-researcher to understand multiscale hierarchical systems, where chemical and physical principles would apply from molecules to self-assembled and organized organisms. A comprehensive knowledge of a structure-function relationship at the level of gene, genome, cell, tissue, organ, and systems, through development, would further add to the knowledge base and the learning outcome in terms of editing of genes and genomes for industrial application and pure research purposes. Short dissertations could be designed around these problems to give the students hands-on training and equip them with skill sets of use in the future, in the areas of future applied aspects of Zoology. The vibrancy to synthesize from the knowledge gained and come out with disruptive outcomes would define the learning outcomes of the future UG and PG students. Such a human resource will be well equipped to cater to the future needs, both in the so-called basic and applied research; which should not be seen as dichotomous any longer. Incidentally, the approach adopted would optimize and reduce the burden of teaching on mentors, though initially a little hard work to shape the contents of the curriculum is required. Teachers would need to be trained for the same as well for a uniform approach to deliver and communicate.

While the above mentioned attributes may be expected of a UG/PG student of Zoology, who studies a specific subject in an integrated and cross-disciplinary manner, in the context of all living systems, and their inter-relationship within the ecosystem, the scale, character and rigour that the student experiences may vary from one institution to the other. The same is likely to be true for other subjects as well. Regardless of the subject, it is mandatory to bring uniformity to the learning outcomes involving the discipline and the corresponding ‘social skills.’ Within the broad-range skill sets related to the discipline, what would be required is to impart and assess the quality of critical thinking, analytical and scientific reasoning, reflective thinking, information and digital literacy, and problem-solving capacity. These are part of a defined set of attributes to be demonstrated by a UG/PG in any discipline, as put forth by the Core Committee on LOCF of UGC.

The approach of teaching different topics across diverse disciplines of sciences, if adopted, connecting the topics with the scope of an application or an appreciation for the same, would instil faith in the public and in future generations as societal needs will be fulfilled. Those who show potential for investigative research can be geared to attempt to answer unique questions of their own curiosity, rather than perform repetitive research of no relevance. After all, the education received and its learning outcome has to result in either the generation of new knowledge or in indirect and immediate societal benefits, or both. Let us not forget that the so-called ‘basic’ of today may attain an application value tomorrow. Clarity in basic and integrated conceptual understanding of subject areas is the key to inventions, discoveries and innovation. It is time to shape curricula and learning outcomes in the higher education system to cater to S&T missions and nation building.
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Promoting a Climate for University Research: OURIIP, the Odisha University Research and Innovation Incentivization Plan

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Introduction

On November 14, 2018 the Minister for Higher Education in Odisha, Mr. Ananta Das released a policy guideline on the Odisha University Research and Innovation Incentivization Plan (OURIIP). The plan provides funding support in three aspects with the aim of promoting high-quality research. The first is to provide fellowships for students pursuing research. The second is to provide seed funding for early career research to the faculty across universities in the state, and the third is to support high-quality publications. The details of the scheme are given in the attached brochure, and in this introduction, I briefly discuss the motivation behind the OURIIP.

The best way to define Higher Education is a process that goes about creating a better tomorrow for all of us. There are four main constituents of higher education today namely, teaching-learning, competency development, research – innovation, and inculcation of a value system. In its efforts towards raising the level of higher education to global excellence, the state of Odisha has introduced a large number of reforms in each of these sectors. Some of them include capacity building, governance changes, examination reforms etc., and these are already being introduced in the state universities.

Research and Innovation is the heart of knowledge, a means to create livelihood and the benchmark of global excellence in the new millennium. The present government of Odisha
Promoting a Climate for University Research: OURIIP, the Odisha University Research and Innovation Incentivization Plan

was quick to realize it. The state of Odisha has been trying to address the lacunae like inadequate sophisticated research tools, e-libraries, scarcity in competitive research funding in terms of early career grants, lack of full-time research scholars in state universities, etc. While a few of these are being addressed through the World Bank loan assisted project, Odisha Higher Education Program for Excellence and Equity (OHEPEE), the issues related to full-time research scholars and the seed research grants needed to be addressed through a different scheme.

In this context, this new scheme OURIIP will provide about 175 state junior research fellowships (5 in each subject for 35 subjects) @ Rs. 15,000/- per month for four years (+1) or on completion of PhD, whichever is earlier. The CSIR-NET qualification is kept as the minimum eligibility for the scholarship. The candidate has to complete her work as a full-time scholar at any state university of Odisha and publish quality papers in Science Citation Index (SCI) journals for the continuance of the fellowship. A novel monitoring scheme through an annual Scholars Conclave is designed as the platform for review, and it is expected that this will increase annual research publication by at least 150 good papers per year. At the end of five years, the state should have more than 700 full-time research scholars producing excellent output in terms of publications and patents. The annual outlay would increase by Rs. 35 million until it steadies at Rs. 175 million after 5 years. Keeping equity goals in mind, 40% of fellowships will be reserved for women researchers.

Beyond the research students, young faculty below 40 years of age play a key role in contributing to R&I footprint. In the second part of the OURIIP proposal, young faculty will be encouraged to compete for a seed grant of Rs. 500,000 for a two-year period. Proposals will be reviewed, assessed and up to 40 seed grants in all subjects including technical areas will be sanctioned annually. In the next five years, this should induct about 200 young faculties into the R&I culture. The Scholars Conclave will also be the common platform to monitor their progress.

The third part of OURIIP provides publication support to outstanding journal publications. This initiative is expected to expand and revitalize the research-innovation culture/footprint in the state universities of Odisha. This scheme will be implemented by the State Higher Education Council on behalf of the Higher Education Department of Odisha Government.
Odisha University Research and Innovation Incentivization Plan (OURIIP)

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Odisha University Research and Innovation Incentivization Plan (OURIIP)

Odisha State Higher Education Council (OSHEC)
2nd Floor, Odisha State Bureau of Text Book Preparation and Production
Pustak Bhawan, A-11, Suka Vihar, Bhubaneswar - 751022

Higher Education Department,
Government of Odisha
2018
1. Preamble

In the changing dynamics of higher education a new world order in terms of the knowledge based economic and socio economic change vis a vis knowledge awareness has been rapidly emerging across nations. Developing nations are rapidly transforming their higher education strategies with wide ranging reforms in teaching learning strategies, research – innovation plans and skill development sectors to be in line with the market requirements and with quality of students at par with that of the developed nations. The mission of all higher education programs now represent a symbiosis of knowledge, skill, livelihood-creation, environment conservation and value system integration in the student.

The practice of research and innovation has been widely accepted as the most essential component of a developing country’s repertoire of higher education. While research contributes to creation and application of new knowledge, innovation not only incites deeper understanding but parallel thinking regarding value creation out of research. The value creation can be commercial or directed towards societal philanthropy aiming at large scale value addition to human livelihood. It has also been proven beyond doubt that developing a research and innovation culture in colleges and universities improves the learning effectiveness of students and incites the spirit of inquiry in them. Therefore, the quality of a higher education institution is being measured in terms of its research and innovation footprint and their impact on the national/international arena. The systems of knowledge production now include not only universities but also public laboratories, research centres and think-tanks run by policy and civil society groups, industry, the private sector, and the military complex. In fact, these systems have undergone profound transformation to emerge as the main engines of development in a globalized world. Therefore, one now sees major changes in the landscape of higher education, notably in the university sector. Consequently, countries across all regions worldwide are facing increased demand to strengthen their capacities for research and knowledge production. These challenges have become particularly overwhelming for middle - and low-income countries, thus increasing the risk of their further marginalization. Similarly, there is a new focus on knowledge generated by research to be applied to and be the basis of sustainable social development.

If we look at the contribution of India to major global research outcomes, success has been few and far between. As a nation with a large contingent of researchers both in mission departments as well as universities, a large number of publications do come out but very few of them are in the path breaking research category. At the state level, universities in the state of Odisha have developed a good basic teaching learning protocol but show extremely poor research outcome.

In the above context and to bridge the gap in research activities in the state, a new scheme called the ODISHA UNIVERSITY RESEARCH AND INNOVATION INCENTIVIZATION PLAN is proposed for implementation from the academic year 2018-19. The aim of the scheme is to facilitate a research-innovation culture in the Higher Educational Institutions (HEIs) of the State.
GUIDELINES FOR
ODISHA UNIVERSITY RESEARCH AND INNOVATION INCENTIVIZATION PLAN
(OURIIP)
(ଓଡ଼ିଆ ପରିଣାମର ଅର୍ଥର ଜନମାଜୀତ ଅବିଶ୍ଲେଷଣା ପ୍ରକାଶପତତା)

Odisha State Higher Education Council(OSHEC) in the Higher Education Department, Government of Odisha has envisaged a new scheme called the “Odisha University Research and Innovation Incentivization Plan (OURIIP) (Odisha Vishwavidyalaya Anusandhan ebam Abhinavikarana Protsahan Yojana) to bridge the gap in research activities and promote research in emerging areas. Thrust area would be on original research instead of incremental research. The aim of the scheme is to facilitate a research-innovation culture at Higher Education Institutes of the state.

Objective:

The objective of the project is to provide scholarships to talented youngsters to devote themselves to full time research in Odisha and facilitate young faculty to start a research program in Odisha. The scheme particularly emphasizes to facilitate women researchers of Odisha.

There are three components, under which financial assistance will be provided to strengthen the Research, Development and Innovation Ecosystem in State Universities and Higher Education Institutions of Odisha.

(A) Research Fellowship
(B) Seed Funding for Young Faculty working in State Universities and Colleges
(C) Support for Publication related expenses

(A) For Research Fellowship:

Eligibility:

1st Category: It is proposed to provide a Research fellowship to the top ranking NET qualifiers (leaving aside the JRF) in each subject who has not been found eligible for National Junior Research Fellowships for doing research in state universities.

The applicant for the scholarship must be a permanent resident of Odisha.

Advertisement inviting Applications:

The OSHEC shall invite applications from eligible candidates through advertisement in local newspapers and/or the websites of the Higher Education Department. The format of application and guidelines are available in the website of HE Department (www.dheodisha.gov.in).
**Tenure of the Fellowship:**

The period of fellowship will be limited to 04 years, extendable to another one year with the prior approval of the Odisha State Higher Education Council (OSHEC).

**Fellowships:**

The candidate would be eligible for receiving the following financial assistance:

| Fellowship | Rs. 15000/pm with a contingency of Rs. 25000/- per year for subjects having laboratory work and Rs. 15000 for subjects without laboratory work. |

**Number of Fellowship:**

The number of fellowship in each subject would be limited to five (05) with two (02) numbers of fellowships reserved for girl students exclusively.

*Subjects at Masters Level (MA, M.Sc., M.Com.) covered under this scheme (Participants must have cleared NET (UGC, CSIR, DBT, ICAR etc.), conducted by Nationally recognized Agencies in areas relevant to these subjects):*

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Relevant NET subjects will be as defined by the State Universities.
Selection Process:

1. The candidate must be below 30 years of age as on January first of the year in which the fellowship award is being made.

2. Candidate must be NET qualified in any one of the above subjects. Those who are JRF qualified will be eligible for UGC/CSIR/DBT/ICAR fellowship and will not be considered here.

3. Candidates who qualified at NET more than three years back to the year of application will not be eligible, i.e., to be eligible in 2018, NET qualification must be of 2015 or after.

4. The fellowship shall be available only for pursuing full time Ph.D. programme in/under any Govt. university of the State or any State Govt. Institute established in the State.

5. The prospective researchers will apply to the state government citing their NET eligibility certificate, mark sheet/Rank and clearly indicating the specific subject, topic, specific state university where research will be carried out.

6. The student must have registered under an approved research guide after completing the required course work at any of the state universities of Odisha.

7. The OSHEC will be responsible for administering the entire program and procedure for State Research Fellowship as well as the seed funding.

8. The scholarship continuance will depend upon the annual review by domain experts at the Odisha Research and Innovation Conclave. If the work is evaluated to be below 5 on a scale of 10, scholarship will be discontinued.

9. The scholar should not be getting any other financial support from any other source and be a full time research scholar.

10. Selected candidates should be willing to teach at PG/UG level at least 3 hours per week.

11. Candidate would be willing to provide a bond to complete the research work as a full time scholar and submit for Ph.D. within a period not exceeding 4 years. If it has to be extended to 5th Year, it has to be on prior approval of OSHEC.

12. The selected candidate shall remain under the administrative control of a Supervisor. The Supervisor must be a regular faculty/recognized guide of any Govt. University of Odisha/Govt. or Aided Colleges or a regular Scientist of any State Govt. Research Institute of Odisha or any Central Govt. Research Institute established in Odisha.

13. All correspondences of the Scholar should be routed through the supervisor, Head of the Department and Head of the Institution concerned.
Release of Fellowship & Fund:

1. The fund with respect to fellowship shall be made available to the Head of the host Institution by the OSHEC/HED.

2. The fellowship shall be directly credited to the bank account of the scholar on monthly basis by the Head of the host institute within the first week of the month.

3. The contingent grant shall be credited to the bank account of the scholar/Head of the Institute.

4. The host Institute/University/College shall submit the financial year wise audited statement of Expenditure & Utilization Certificate in OGFR 7(A) in duplicate countersigned by the competitive authority for each fellowship.

5. The Fellow will be required to submit progress report every year through proper channel.

Cancellation/Withholding of Fellowship:

1. The fellowship shall be discontinued if it is found that the candidate has furnished incorrect information or suppressed materials. In such cases, other disciplinary action will be initiated against the candidate as deemed fit to recover the fellowship amount.

2. The fellowship shall also be discontinued while pursuing Ph.D. Degree if the conduct of the scholar is found to be unsatisfactory, as per the report by the Committee of three members comprising of Head of the Department, Supervisor and one outside subject expert to be constituted by the concerned Department of the University/Institution/College.

3. The fellowship will be automatically cancelled if a candidate changes the Course of Study for which she/he is in receipt of the fellowship under this scheme or the progress is found unsatisfactory during review.

Other Conditions:

1. The Higher Education Department, on the basis of request of OSHEC with justification, may increase the amount and number of fellowships with due concurrence from Planning & Convergence Department and Finance Department, Govt. of Odisha.

2. In general, the Fellow once accepts the offer of fellowship at a particular University/College/Institute shall not be allowed to transfer the fellowship to any other University/College/institute during the tenure of the fellowship. However, under unavoidable situation, the fellow must seek prior permission from the Higher Education Department, Govt. of Odisha through OSHEC for transfer of Institute through written application with the following documents.

   ✓ No Objection Certificates (NOCs) from both host Institutes and Supervisors

   ✓ Detailed Justifications for changing/shifting of host institute for implementation of fellowship
✓ Area of Ph.D. Work with an up-to-date progress report
✓ Curriculum vitae of research supervisor at the new host institute
✓ Up-to-date Financial Statement from the old host institute

3. In case of discontinuity of the research project by the scholar, the Institute concerned shall return the unutilized funds to the OSHEC immediately. Further, the scholar is required to hand over the research findings to the OSHEC through proper channel.

4. In case of suppression of facts regarding receipt of any other fellowship from any other Govt. and/or Private Institutions, the scholar is required to refund the total grant (with interest) received from HE Department through OSHEC.

(B) Seed Funding for Young Faculty working in State Universities and Colleges:

1. Any Young faculty with a Ph.D. and below 40 years of age working in a regular capacity in State Universities and Colleges (Government & Aided) under Higher Education Department and also in State Government Technical Colleges/Universities under Skill Development and Technical Education Department can apply for this seed funding with an appropriate research proposal.

2. The proposal will be prepared in the standard format that will be uploaded in OSHEC/HED website.

3. She/he has to submit a proposal in the prescribed format for review followed by a presentation. The funding will be decided on merit.

4. The quantum of each seed funding will be limited to Rs. 5 lakh per faculty and duration of two years will be the period for providing the deliverables.

5. Faculty in receipt of funding from other research agencies will not be eligible for this scheme.

6. The state will annually award 40 such seed funding on competitive basis after due evaluation of the proposals by a domain expert committee.

7. The seed funding scheme will expect the concerned faculty to produce about 2 research publications (at least one in Scopus Indexed Journals) per year. They will also be expected to write and secure funded research projects from national agencies towards the end of the two year period.

8. Annual Review of Work would be done through a poster presentation at Odisha Research Conclave.

(C) Support for Publication related Expenses:

If a faculty in State Universities or Government or Government aided Colleges under Higher Education Department or State Government Technical Colleges/Universities under Skill Development and Technical Education Department publishes in extremely high impact journal that is also appearing in SC indexing (Science Citation indexing), there will be a provision to subsidize 50% of the publication cost limited to Rs.25000/.
However, in exceptional cases where publication is approved in a globally renowned journal like Nature etc., and higher cost is indicated, the request can be taken up as a special exceptional case.

In case eligible candidates in any area are not found, no scholarships will be awarded and it would also not be carried over.

**Monitoring of Fellowship in Odisha Research Conclave:**

The scheme will also include few annual thematic research conclaves titled, “Odisha Research Conclave” for these research scholars of the state, where they will showcase their work and be reviewed and be mentored by domain experts with awards for best research work in a category. An amount of Rs. 30 lakh is earmarked annually for conducting these conclaves. The money will be used in TA, stay, hospitality and other contingent expenditure for these events. Annually three conclaves; one in each faculty, i.e., (a) science, (b) social science and liberal arts as well as (c) business, economics and commerce will be organized. These conclaves will provide the much needed platform for review and monitoring.

**Executing Agency:**

The entire scheme will be operated and executed by the Odisha State Higher Education Council with funds sanctioned from Department of Higher Education. Committees will be formed with the domain experts as members. Vice-Chairperson of the OSHEC will prepare the list of the Members and submit to the Government for approval.

**Timeline:**

1. **For Research Scholarship:**
   a. Advertisement before March every year
   b. Selection and award before May in the same year

2. **For Seed Funding:**
   a. Advertisement twice a year preferably January and July
   b. Selection and award by March and October

3. **For Research Scholar’s Conclave:** December every year

4. **Reviewing/Mentoring Panel:** to be drawn up by OSHEC

The implementation of the scheme, the funding pattern and outcome of the scheme will be reviewed annually by competent authority. The Higher Education Department, Govt. of Odisha, with the advice from OSHEC reserves the right to amend the rules. The decision of the competent authority shall be final and no body/individual can go for any legal or other remedy against the decision of the competent authority.
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