

Commentary

The Universe – Which Tools to Understand It¹

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It is my great honour and privilege to participate and speak during the celebrations of the 350th anniversary of the French Academy of Sciences. On this momentous occasion, I bring to you all good wishes and words of appreciation from the nearly 1000 Fellows of the Indian National Science Academy and more than a billion people from India. It is a matter of great pride and satisfaction that India and France, and especially our respective science academies, have enjoyed close and fruitful cooperation, which I am sure will only strengthen in the future.

I have the challenging task of speaking on “Understanding the Universe”, no less, and indeed, to identify the tools that may be required to do so. From the title of this session, I believe I am entitled to take the liberty of thinking of this as a futuristic adventure. Being the last speaker gives added justification to my futuristic assumption about this task. So, what tools might we need to understand the universe in the future? Needless to say we must first survive in order to understand the universe but we also need to understand the universe in order to survive. But it is hard as they say, to make predictions, especially about the future! What might the future hold for humanity?

We may face the threat of annihilation from within or from without. Can we understand human nature enough to prevent mutual annihilation? I might venture to add that ever-increasing security alone may not be adequate to prevent mutual annihilation; we

will need to understand human nature. Can we successfully deflect large objects from space that might be on a path of collision with the earth, every single time? We may face extinction due to global warming and if we survive that, then may be from global cooling a little bit later. I will not even speak about new diseases as it no longer sounds futuristic enough! We may indeed discover life elsewhere in space and/or be invaded by aliens. Or we may begin to relocate to another planet after making the present one unliveable. On perhaps a more pleasant note, we may achieve near immortality, or at least live for hundreds of years. I am not sure though, how pleasant this will be especially, if as I suspect, we fail to conquer disease and suffering. We might read each other’s thoughts directly, without the need for language or any kind of active communication, and we may be forced to do so whether we like it or not. We might be able to transplant memories and experiences between individuals and even transplant whole brains? Who knows?

The distinguished British-Indian biologist JBS Haldane once wrote, “I have no doubt that in reality the future will be vastly more surprising than anything I can imagine. Now my own suspicion is that the Universe is not only queerer than we suppose, but queerer than we *can* suppose” (Haldane, 1925). How can we prepare for such an unpredictable future? Which tools indeed, do we need? I would argue that we cannot make any meaningful predictions about the future, much less about the tools we would need

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in the future, no more than the founders of the French Academy of Sciences 350 years ago, could have predicted which tools we would need in the 21st century, even those needed just to conduct this meeting!. What then can we do? In my opinion, all we *can* do, and all we *need to* do, is to nurture the human mind, the minds of future generations of humans, the single most important tool that will allow is to invent and construct whatever other tools we might need at any time in the future, to face any contingency, good or bad, pleasant or otherwise. I am confident that the human mind has infinite potential to meet any challenge. But there is a problem. The human mind is not just the product of our genes; instead it is the product of the interaction of our genes with our environment. We will soon be very good at taking care of our genes, fixing bad ones, and even creating new ones. But as the Harvard biologist Edward O Wilson (2015) has so elegantly argued, we can fix our genes to cure diseases and live longer but cannot do so to improve our minds – why?, because we do not know and *cannot* know what is meant by an ‘improved mind’. Our minds are self-organized miracles that emerge with infinite potential and infinite variety, and they are our best hope. But what about the environment needed to develop our minds. Here we have multiple challenges. We cannot promise that we will not meddle with the environment because, we are the environment. We can easily cause great harm and direct the trajectory of the development of the minds of future generations in wrong directions - indeed we are already doing so. On the other hand, we can nurture growing minds and facilitate them to achieve their full potential, without moulding them to our specifications. This is our biggest hope and biggest challenge.

The human species is remarkable in having an extraordinarily long period of ‘immaturity’ - a very long period of learning. This is when the environment interacts with our genes to produce our adult minds. It follows then that the kind of environment we grow up in has a profound influence on the shaping of our minds. This fact is beginning to be slowly recognised in the context of parenting. In her recent book, *The Gardener and the Carpenter*, the distinguished child psychologist from the University of California, Berkeley, Alison Gopnik (2016) has argued most convincingly that as a parent you should not be like carpenters and, “shape [children] into a final product

that will fit the scheme you had in mind to begin with”. Instead she suggests that you should be like a gardener, and “create a protected and nurturing space for [children] to flourish” and thus “help create a new generation that is robust and adaptable and resilient, better able to deal with the inevitable, unpredictable changes that face them in the future”. Now, if this is good advice for parents, I think it is even better advice for teachers.

I will argue that our present system of education is fundamentally flawed and incapable of nurturing minds as tools that we will need to understand the universe in our unpredictable future. The list of its flaws is a long one. We feed students with facts rather than teach them how to think. We destroy their curiosity and creativity and replace them with ‘knowledge’. But that knowledge is our knowledge, it is knowledge of the past and may be quite useless in the uncertain future. It is my frequent experience that the less educated a student is, the brighter and more intelligent she is; the more likely she is to be able to solve a problem *de novo*. I often have to *cure* my students of their education before I can nurture them into thinkers and problem solvers. Alison Gopnik makes a distinction between goal directed, “Exploit learning” and aimless, playful “Explore learning”. We have all but eliminated exploration and play, from pedagogy. Thus we inevitably mould students to be like us, to gain the knowledge we have gained, to master the skills we have mastered and hence to be doomed to be fit only to live in our universe. But they *will not*, and *need not* live, in our universe. They *will not* because the universe will change in unpredictable ways, and they *need not* because they may create a much better universe of their own.

But how can we prepare future generations of minds to reinvent the universe and be capable of inventing tools to understand their universe? We cannot ‘*prepare*’ them, but we can ‘*nurture*’ them - like gardeners, not like carpenters, to borrow Gopnik’s metaphors. An analogy from evolutionary biology may be useful here. A major paradox in evolutionary biology concerns why sexual reproduction is so overwhelmingly common in the living world, although asexual cloning is so much more efficient. An attractive solution to this paradox is the so called Red Queen hypothesis which argues that sex is a *gamble* against disease Hamilton *et al.*, 1990). Disease

causing parasites have such short generation times that they undergo hundreds and perhaps thousands of cycles of reproduction by the time we have completed one generation. This means that by the time we have barely completed one generation, natural selection has had enough time to perfect our parasites to overcome our defences and kill us with ease. If we now produce children as clones of ourselves through asexual reproduction, we would hand it to the parasites on a platter – they would drive us to extinction in no time. What we do instead, is that through sexual reproduction, by mixing genes from two different parents and by further recombining previously existing aggregations of genes, we play dice, and produce children with new and wholly unpredictable combinations of genes. The old tricks of the parasites are now useless and they have to start all over again. Like the Red Queen in Lewis Carroll’s *Alice in Wonderland*, the parasites have to keep running to stay in the same place!

I think we need to do something similar in nurturing new generations of minds. Create a vast and unpredictable variety of minds that can reinvent the universe. By nurturing curiosity and innovation and letting students rediscover the laws of nature for themselves, by not just tolerating, but actively encouraging, variation and messiness. Alison Gopnik

argues that “from brains to babies to robots to scientists, mess has merits. A system that shifts and varies, even randomly, can adapt to a changing world in a more intelligent and flexible way”. We must not teach students the laws of nature as we understand them. Instead, we must let them discover the laws of nature, by giving them opportunities to solve puzzles and paradoxes, to invent the tricks they need and discover the facts they need. Rather than feed them we must teach them how to cook, to use another analogy. We must not expect our students to learn our knowledge and master our skills more efficiently than we did, just because we had to learn from scratch and they can directly get the final product. We should not tell them “Don’t make the same mistakes that we made”; instead we must let them make their mistakes. It is the making of mistakes that allowed us to learn. We all learn much more from failures than from successes (Dennett, 2014).

By thus completely reinventing education, by standing the present system of education on its head, by playing the role of gardeners rather than of carpenters, we should nurture the growth of a plethora of creative and innovative minds in the future, very different from our own. And it is *these minds that are the tools* we will need to understand the universe.

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