What is scientific thinking? Two cases of problem-solving by some newcomers in science

Deepanwita Dasgupta and Alexander Levine

'We can avoid, above all, the mistake of thinking that unless one is big one is negligible.'

– Fred Hoyle
Motives and Aims of the Scientist

What is scientific thinking? Is it confined only to the thought processes of a professionally trained community whose members possess high levels of expertise, and work with sophisticated equipments? In the recent issue of February 2014, *National Geographic* covered some sophisticated researches on neuroscience and brain imaging done at the Martinos Center for Biomedical Imaging in Boston, MA, USA. The Large Hadron Collider has often been cited as the iconic symbol for big science in our times. If science means only activities of this type, carried out at specialized laboratories and sites, then that would be rather depressing news, for only a few countries and communities would have access to such expensive set-ups. But what if scientific thinking rests on something quite different? This should give us hope for the future, for then a larger group of stakeholders could engage in it. But the question is, can there be any real breakthroughs from such modest sites, and from people who work with relatively humble, and perhaps not-so-very-sophisticated, equipment?

This article is an attempt to shed light on the cognitive and the social processes embedded in scientific activity that often show up in the work of the newcomers who enter a scientific practice from a very modest and marginal situation, and work in spaces peripheral to the main communities. In this article, we shall briefly analyse a couple of such cases of problem-solving, which show remarkable levels of self-training. We shall claim that the ability for such self-training is a prominent hallmark of scientific thinking, and that such thinking can arise anywhere and in many different circumstances. Thus, the domain of science may often include many unlikely contributors and stakeholders, and is not necessarily confined only to a professionally trained community. To illustrate this through some examples, we shall briefly explore two cases of problem-solving by two rather unlikely contributors – one taken from the history of Indian science, and the other from recent events. Our first example will be the case of the 'lion lights', a set of flashing LED lights fixed onto a cattle fence, designed in 2011 by a 13-year-old Maasai boy named Richard Turere during his frantic efforts to keep wild lions away from his family's cattle. For the second, we shall look at some very early musical researches done by C. V. Raman while he was still an amateur and was trying to figure out the acoustics of the violin. Raman went on to have a career long and distinguished in the sciences, while the track record of Richard Turere is yet hidden in the future. However, both were unlikely contributors to a scientific practice of any kind, for both were somewhat peripheral individuals – one who has had, so far, no training in the sciences (Turere), and the other who had received some training (Raman), but who then sought to turn himself into a creative researcher in the sciences via some inspired self-training. Turere has created an important invention that addresses the complex issue of human–animal interaction, essential for both ecology and conservation in our day; and as an almost-unknown peripheral newcomer in 1910, Raman designed a simple mechanical violin-player that successfully helped him to test his theory of the properties of bowed violin strings, and thus made him a contributor in the practice of musical acoustics.

Both these cases display qualities of problem-solving, an old hallmark of scientific thinking. But they also display additional features. First, in both cases we see the grasping of a problem or a research programme, some self-training, and finally the adaptation of bits of information or some at-hand material to shape an outcome that took the protagonists to a new level. From that level, they were able to set up themselves to solve yet more complex problems. In this way, these contributors succeeded in accomplishing a few things – first, in gaining a first foothold inside a new practice by grasping something new from the outside, and being able to go one step further in that direction by creating an outcome or a product. Second, they also gained the ability to train others, thus initiating a chain of (potential) trade with another community. In more formal technical language, they created for themselves bits of 'contributory expertise' in science[1], which could then start a new practice at their home ground (if sustained long enough). Not surprisingly, such processes began with some inspired self-training, and led to some form of trade with another community. It also created a small group of people – or at least one individual – who thereafter had the potential to develop a new practice, and could thus function (at least in principle) as a contributor to the practice of science, and trade the results of his or her practice with another, and perhaps more established, community. A multi-level ability of this kind, we argue, lies at the heart of scientific thinking.

The invention of the 'lion lights'

The Nairobi National Park borders on the modern city of Nairobi, Kenya. On its southern, unfenced edges live the Maasai community, who are traditional cattle herders. The Nairobi National Park is home to many kinds of wildlife, including lions, but the urban expansion of the city is putting pressure on the lions of the Park by taking away their habitat and their natural prey. The lions therefore frequently raid the nearby Maasai villages for food, and in that process kill their valuable cattle. The villagers retaliate either by killing the lions or by poisoning them, thereby severely depleting the already endangered lion population. A struggle between the two is usually lethal on both sides, and today this human–wildlife conflict is a major problem for conservation everywhere. (India experiences a similar problem with elephants around the Himalayan foothills. They often get caught in the railway lines, and are thus killed as a result.)

Thirteen-year-old Richard Turere found himself squarely in the middle of this deadly conflict. Turere belongs to the Maasai community, and according to their customs, when a boy becomes six years old, he becomes responsible for protecting his family's cattle. This custom brought Turere into full conflict with the lions, for they would constantly try to kill his father's livestock, in which they were mostly successful, and Turere would usually fail to prevent this from happening.

To solve this acute problem, Turere tried different approaches – first using fire, then the usual scary stick figures. None of them worked for more than a couple of days. However, one night, quite by accident, he discovered that the lions are afraid of moving lights – they did not come into attack when he was moving around in the cowshed with a flashlight in hand. Trying desperately to capitalize on that discovery, Turere designed a system of 'lion lights', i.e. a cattle fence mounted with some outward-facing LED lights, which blink and flash in an alternating sequence, thereby giving the impression that somebody is moving around in the shed with lights in hand. To power those blinking lights, Turere used a battery and a solar panel; an indicator box and a set of switches to turn the lights on or off completed the rest of his network. At nightfall, the LED-lighted fence would be turned on, and the alternating flashing of the lights would give lions the impression that somebody was moving around in the cowshed. This invention has kept the lions away from Turere's livestock for the last two years.

The fence solved Turere's problem, and the lions have since then stayed away from his family's livestock. News of this invention spread quickly, and Turere was soon invited to install his 'lion lights' for the other Maasai families. Finally, the news of his invention reached the Kenya Land Conservation Trust and Paula Kahumbu, CEO of WildlifeDirect, and it was also reported on CNN. In 2013, Turere was finally invited to give a 7-min TED talk in Long Beach, CA about his invention. This short video has since then been viewed 1,143,418 times[2], and his invention has since then been used to solve other similar problems with many different predators.

Turere has had no formal training in the sciences yet, except his passing familiarity with a few electronic devices that he had taken apart and re-assembled on his own. (He has, however, already secured an admission and a scholarship at the Brookhouse International School of Kenya, which is one of its best schools, and has expressed the desire of becoming an aircraft engineer.) The key to his invention came from his modelling of the situation in terms of moving lights, which he realized make the lions afraid, and therefore keep them away. This insight gave him an answer to the problem, and a new breakthrough in the shape of an invention. Figure 1 depicts a picture Turere used for his TED talk, showing his audience the structure of his LED-lighted cattle fence.

Making a mechanical violin-player

In 1910, when 22-year-old Raman became drawn to the acoustic properties of the violin, he too was trying to solve a problem. Raman had become interested in the physics of the musical instruments, especially the violin. Specifically, he wanted to know how the various parts of a violin interacted with one another during a playing episode. At this time, he was still trying to teach himself how to analyse wave phenomena, a project to which he had been drawn by reading Herman Helmholtz's *The Sensations of Tone*. In order to do this properly, however, he would have to make some precise and continuous measurements. Since this would be difficult to do with a human player, Raman decided to build himself a mechanical violin-player that would successfully mimic human performance, and thus allow him to test his theory.

Being an amateur of sorts, Raman built a player with bits and pieces of whatever he had available at hand – a disused optical bench, some abandoned bicycle parts, and of course a copy of a Stradivarius violin (Figure 2). The violin moved to and fro on the optical bench on a well-oiled cast-iron track, and the bow remained fixed in its position. The system was well designed to maintain full control over the pressure and the speed of the bow – a damping device and some counterweights were attached to it so as to cut down all unnecessary vibrations.

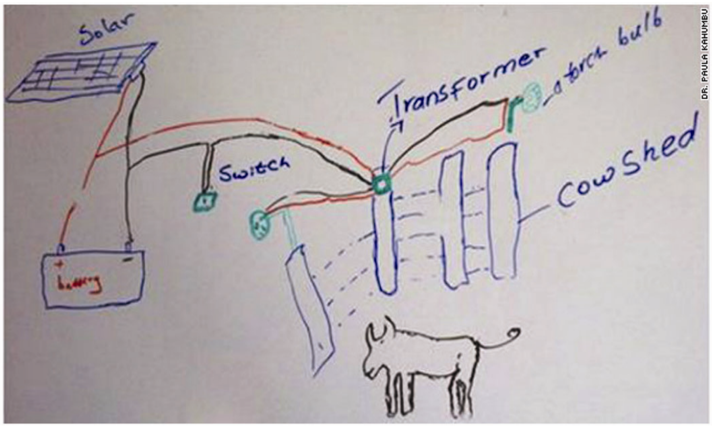

Figure 1. Turere's fence fitted with 'lion lights'.

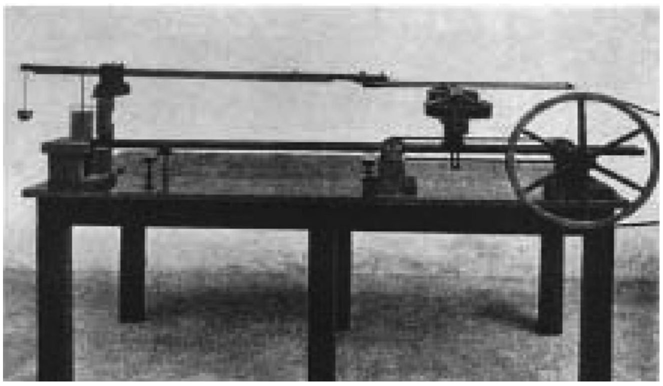

Figure 2. Raman's mechanical violin-player[3].

With this modestly designed equipment Raman set to work on his research problem. Specifically, he tested for four relationships: how changes in the downward pressure of the bow correlated with changes in the position of the bowed region; how bowing speed is related to the bowing pressure; how bowing speed changes with pitch, and finally, the effect of muting.

The player was sensitive enough to produce measurements that allowed him to formulate several sets of simple analytic equations, shedding light on his chosen problems, e.g. laying out the relationship between the bowing speed and the position of the bowed region in terms of two coefficients of friction. He also showed how bowing pressure rises quickly with increase in the bowing speed, the pressure rising roughly in proportion with the speed. Overall, the exercise allowed him to construct a kinematic analysis of how the three sub-systems of the violin – the string, the body, and the bridge – interact and respond to one another during a playing episode. Raman sought to make those relationships visible using a graphical analysis. With those results in hand, Raman succeeded in creating for himself a bit of what Thomas Kuhn called normal science, that he could thereafter use as a stepping stone for analysing even more complex problems of wave phenomena. Within a few years of this research, Raman's attention would shift from acoustics to optics, and his next big project in that direction would be the solution of the problem of the blue colour of the sea. Raman thus gained an entry into the field of acoustics, then optics, specifically the problem of molecular diffraction of light, by his self-training. It is this training that led him to discover his famous Raman Effect. Throughout this optics phase of his career, and during the search for the Raman Effect, Raman adhered to the same basic techniques that he taught himself during his early acoustic phase – always designing simple, intuitive, low-cost experimental set-ups, and then reasoning visually on the strength of such set-ups. In short, through those early modest attempts he established himself as a practising scientist, who is capable of solving complex problems on his own, and in this manner gained an entry into the professional scientific community, then almost completely dominated by scientists from Europe. His subsequent trade with that community allowed him to set up a new scientific practice at home, training new successors who could carry on with the tradition.

Conclusion

These two examples show us that scientific thinking and scientific breakthroughs can arise quite well in circumstances where there exists little or almost zero interaction with another expert professional community. Yet, these are powerful cases of problem-solving that were potent enough to create either a new invention or allow one entry into an established research programme. In more formal cognitive terms, both episodes display source-to-target thinking, and the ability to create a new stock of contributory expertise at a new location. Thus, science is not necessarily only the story of a professionalized expert community during their moments of specialized contributions. Scientific outcome – and thus by extension, scientific ability and problem-solving – can arise in a much larger group of stakeholders, who can create this ability in themselves by various sorts of means, most important among them being the ability to impart self-training. If we remember this, we will be inclined to pay much more attention to many modest beginnings, and perhaps also seek to design an appropriate science policy and science education, which, in the long run, will further such outcomes.

Scientific thinking involves the process of creating new concepts that emerge from situations when an individual develops a response to a problem situation. This might include using models of the problem, applying a number of knowledge-constructing practices, and so on. The reasoning used might also be an extension of everyday reasoning. Thus scientific thinking is not confined only to a few professionalized groups and experts. Very modest set-ups can also exhibit all the cognitive hallmarks of sophisticated scientific thinking.

1. Collins, H. M. and Evans, R., *Rethinking Expertise*, University of Chicago Press, Chicago, 2007.
2. My invention that made peace with lions. TED talk, 2013, On-line video clip; TED.com/talks/richard_turere_a_peace_treaty_with_the_lions (accessed on 15 July 2014).
3. Weidman, A. J., *Singing the Classical, Voicing the Modern: The Post-Colonial Politics of Music in South India*, Duke University Press, Durham, 2006.

Deepanwita Dasgupta is in the Department of Philosophy, East Tennessee State University, Johnson City, TN 37614, USA; Alexander Levine is in the Department of Philosophy, FAO 226, University of South Florida, Tampa, FL 33620, USA.*
**e-mail: dasgupta@etsu.edu*