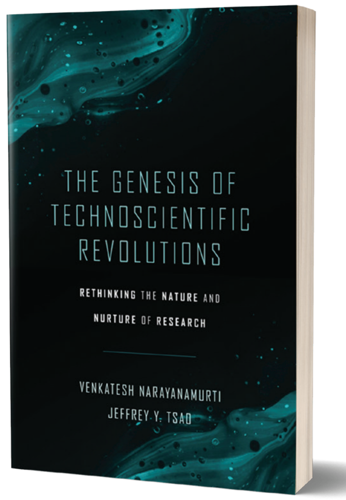
Pairing up

An insightful book argues that technology and science are inseparably related, and that revolutions are created by the two acting as one.



The Genesis of Technoscientific Revolutions: Rethinking the Nature and Nurture of Research

By **Venkatesh Narayanamurti and Jeffrey Y. Tsao**

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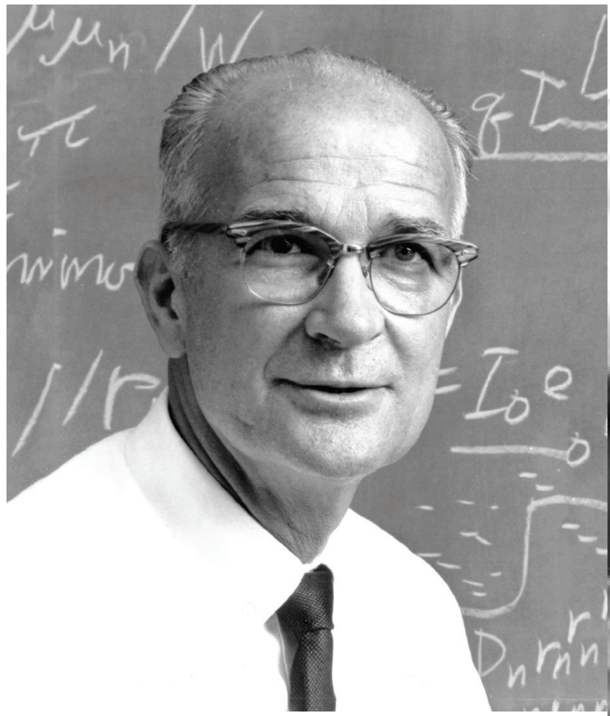
HARI PULAKKAT

Core beliefs of writers often run across their work spanning decades. For Venkatesh Narayanamurti, Professor Emeritus of Technology Policy at Harvard, one core belief is the unity of fundamental and applied research. His book *Cycles of Invention and Discovery: Rethinking the Endless Frontier*, published in 2016, sprung from the belief that there was no real distinction between pure and applied sciences. He argued that creating two categories of research was artificial and harmful, and this practice grew from a poor understanding of the history of science and technology and the nature of invention.

It was not a new observation. In his Nobel Lecture in 1956, William Shockley, the co-inventor of the transistor, had derided the artificial division of research into the pure and the applied. Shockley was forced to say so because such a dichotomy was entrenched in the U.S. at that time, primarily driven by a report by Vannevar Bush, Director of the Office of Scientific Research and Development. Bush's report, called *Science, the Endless Frontier*, argued for a need to support fundamental research and to increase the flow of knowledge from basic research labs to industry. However, in the process, Bush had created an impression that the flow of knowledge was in one direction, from science to technology, and that technology was in a sense applied science. Bush's ideas became the foundation of U.S. science and technology policy. And, by extension, that of much of the world.

In their 2016 book, Narayanamurti and his co-author Toluwalogo Odumosu had argued against a linear model of research in favour of a cyclical model where science and technology fed off each other. An experimental physicist, Narayanamurti had worked at Bell Labs at its prime. After long stints in the Sandia National Laboratories and the University of California, Santa Barbara (UCSB), he was the Dean of the Harvard John A. Paulson School of Engineering and Applied Sciences (SEAS) for a decade. He had been thinking deeply about science and technology policy during the last decade. As he read *Science, the Endless Frontier* closely, Narayanamurti realised that his own experience of innovation was quite different from what Bush had espoused. Bush's biases were clear from the report; he had mentioned the world 'science' 130 times and 'engineering' four times.



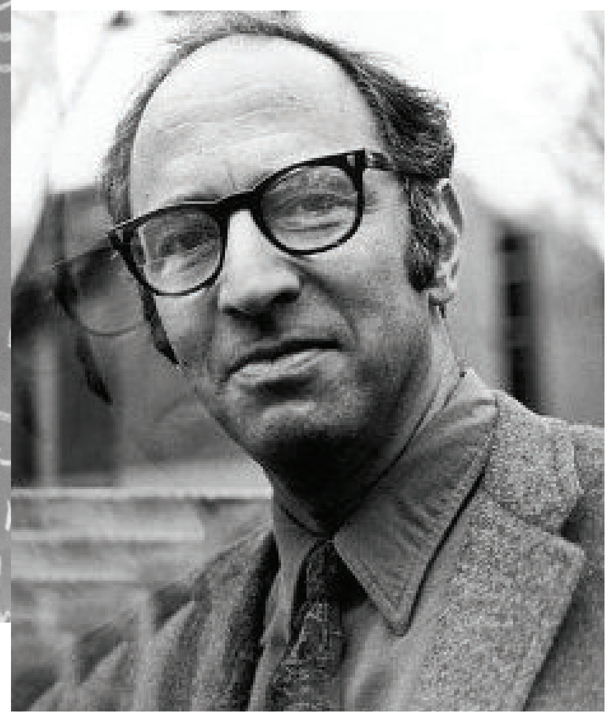
Transistor co-inventor William Shockley had in his Nobel Lecture in 1956 derided the artificial division of research into the pure and applied. PHOTO: WIKIMEDIA

TWO CLASSES OF RESEARCHERS

The idea of technology as applied science has negative consequences to the world of research, whether for nations or for corporations. It divided research into two kinds of activities, each to be funded separately. It created two classes of researchers, the pure and the applied, with tacit notions of superiority of one over the other. It created mutually exclusive territories and led to fierce disputes over what was to be funded as a priority, and two sets of researchers not always seeing eye to eye. Research suffered as a consequence. Corporations, nations, and the world suffered too.

Five years after he wrote his first book, Narayanamurti teamed up with Jeffrey Tsao, senior scientist at the Sandia National Laboratories, to extend the arguments and propose a way for the world to move forward. The new book provides a deep examination of how discoveries and innovations have happened in history, and comes up with a set of methods on nurturing research in public-funded institutions and corporate labs. It is a book that is at once dense and insightful, to be read as much by the shop floor scientist as by the CEO, by policymakers as much as university professors.

The title of the book, *The Genesis of Technoscientific Revolutions*, resembles that of Thomas Kuhn's *The Structure of Scientific Revolutions*. It is unlikely to be a coincidence. Kuhn's book, first published in 1962, was a landmark event in the history and philosophy of science. It introduced the phrase *paradigm shift*, which was later usurped by scholars and laypeople to situations far removed from what Kuhn had described. Kuhn's greatest achievement was to see scientific advancement as a series of leaps followed by steady progress, rather than as a continuous, cumulative advancement. By using a similar title and replacing the word 'scientific' with the word 'technoscientific', Narayanamurti is hinting at two big ideas: that technology and science are inseparably related, and that revolutions are created by the two acting as one and not separately.



Thomas Kuhn saw scientific advancement as a series of leaps followed by steady progress. PHOTO: WIKIMEDIA

MISTAKEN BELIEFS

Early in the book, Narayanamurti and Tsao list three ideas that are widespread but mistaken. The first is that technology is subservient to science and follows from science, and that advances in science are the pacesetter for technological advance. In the first chapter, the authors explain in detail the discovery of the transistor as a case study to disprove this belief. The transistor was made possible through a combination of advances in quantum mechanics and applied solid state physics, by using both science and engineering.

The second mistaken belief is that the goal of research is to answer questions. To the authors, raising new questions is as important as finding answers to them. This misconception has a serious impact on the way research is funded. They mention the example of Einstein's theory of general relativity and its experimental verification as an example of the potential impact of such a belief. Einstein would have found it difficult to get funding for a proposal to ask questions about the nature of space-time, while Arthur Eddington would have got it easily to verify Einstein's theory.

The third mistaken belief is the primacy of short-term returns on invested capital. This belief blinds us to the value of long-term and public return on invested capital. Path-breaking research seeks surprise, and its true impact cannot be predicted. This is true for both government-funded and private research. Great corporate research labs – which have unfortunately become a thing of the past – created the germ of information theory, detected the remnant radiation of the Big Bang, demonstrated high temperature superconductivity, and produced the Scanning Tunneling Microscope, among a host of other advances.

WAY FORWARD

In the core of the book, over 150 pages, the authors provide a way to move forward from these misconceptions and nurture research and development in the future. They do these by creating what they call 'stylised facts'. The first stylised fact is that science and technology are separate categories of human technical knowledge but evolve together and create new science and technology through feedback loops. The second fact is that both science and technology evolve through question-answer pairs, one set of pairs producing another set of pairs, and thus ad infinitum. The third fact resembles Kuhn's paradigm shift: knowledge evolves through consolidation and surprise, as a gradual evolution followed by sudden advances.

Looking at science and technology or research and development through this lens of stylised facts provides ways of nurturing them to produce a healthy society. Here are the key ideas. Research should be funded and nurtured in its own terms, as a specialised activity, providing full scope for twists and turns along the way. The modern tendency, especially in the corporate labs, to 'de-risk' research turns it into development and defeats its very purpose. The authors say that organisations should invest in research only if they can accommodate the unexpected. This is hard for private companies, as accommodating the unexpected often requires a change of business trajectory.

Research seeks to surprise and overturn conventional wisdom while development seeks to consolidate it. So, research should be culturally insulated from development but not intellectually isolated. The project-based culture of development can stifle the people-based culture of research, which seeks meta-goals instead of immediate business goals. It is hard to derive business advantage from knowledge and harder to do so from unanticipated knowledge. However, the meta-goal of research is to create surprises. One way to meet this meta-goal is to fund people and not projects, and create leadership that can culturally isolate research from development and yet produce intellectual collaboration between them. This is hard to do, but great leaders manage it.

The book is a thorough study of the nature of science and technology. Its diagnosis of the ills of science and technology as they are practised now is original and its prescriptions are thought-provoking. At its heart, its message is the centrality of research and development to society's well-being, and the need to reinvent ways of nurturing them. •

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