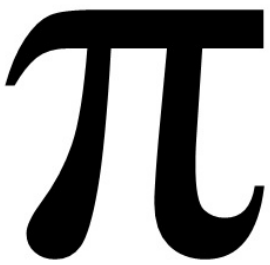
http://www.ideals.illinois.edu/handle/2142/27667 **Number 21** | December 1, 2013

A simple qualitative, yet mathematical model powerfully illustrates how breakthrough innovators come to know

Flatland: Its π-shaped inhabitants

Breakthrough innovators are well-described as multi-dimensional individuals



In the last essay (*Flatland: A glimpse of things to come*) we embarked on a journey, one that eventually will propel us into new dimensions of insight.

Beginning with the simple framework depicted herein with Figure 1, I noted that a breakthrough innovator's "know what" base of factual information serves as the input to their "know how" of innovation skill, with the result being the emergence of innovative insight, a new "know what" output.

Now, we can begin to dissect this model. With the present essay, we will explore and develop the "know what" aspects of this model, the initial "know what" input to innovation and the new "know what" innovative output. In the next, we will consider the "know how" of innovation. Only after laying such groundwork can we bring these elements together in order to see how they work as one, illustrating how breakthrough innovators come to know what to do today in order to succeed in the future.

The initial "know what" input to innovation

Many have recognized that breakthrough innovators bring both depth and breadth in their disciplinary knowledge base.[i] While academic researchers typically are characterized by their profound depth of insight in one field of study and dilettantes by their shallow breadth, industrial innovators are often anecdotally described as "T-shaped" in that they know a great deal about their primary discipline (the vertical stem of the "T" represents the depth of their knowledge) and something about many other disciplines (the horizontal bar at the top of the "T" represents the breadth of their knowledge). Further, some have observed that breakthrough innovators are "π-shaped" or even "M-shaped" in that they exhibit significant depth in multiple fields (two for the "π-shaped" or three for the "M-shaped").

Additionally, apparently-insignificant insights are regularly observed to disproportionately pave the way to significant breakthrough innovations. Similarly, ever-so-slight differences between two competitors often result in significant differences in ultimate financial performance and success as breakthrough innovation unfolds.

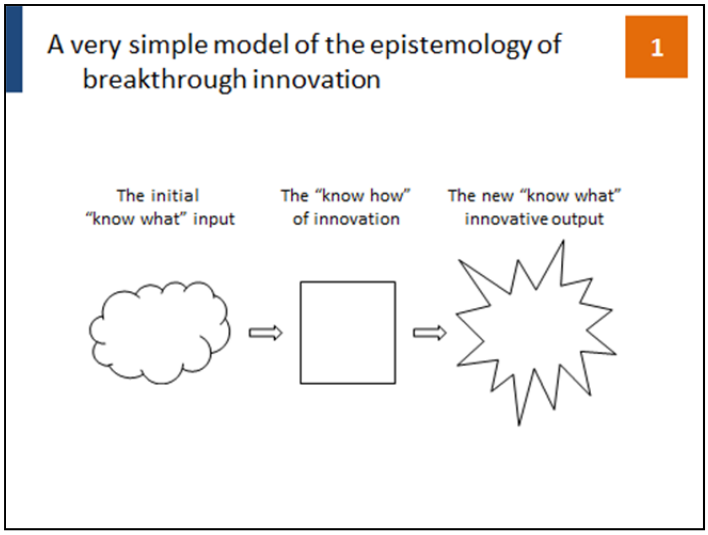
The new "know what" innovative output

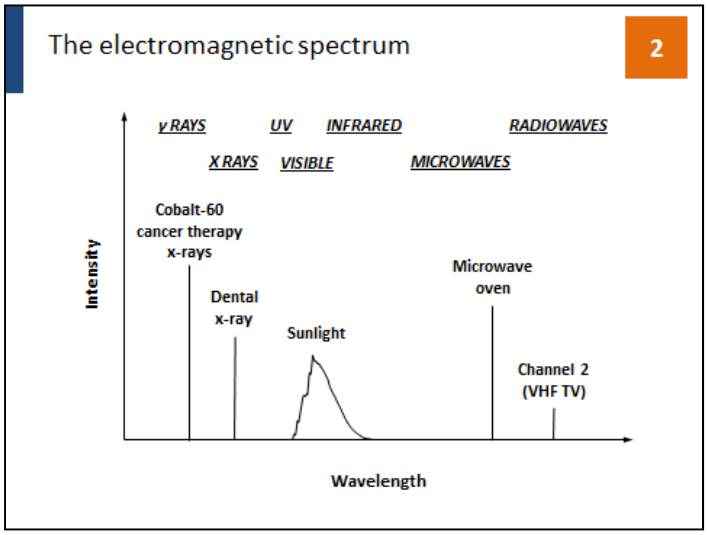
Truly innovative output is disruptive, unpredictable, unexpected in its appearance.[ii] Further, breakthrough innovation, by the very use of the adjective, implies a transition from non-existence to existence of an innovative insight, not unlike the mental image elicited by considering an object "breaking through" a wall – at first it does not exist on the far side of the wall, later it is fully present. Regardless of whether the transition is abrupt or emergent, the difference between input and output is the emphasis here.

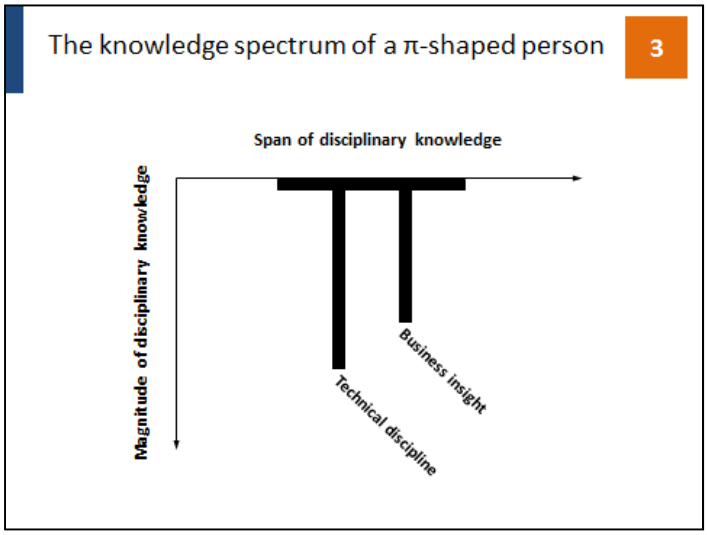
Only after laying the groundwork in the next few essays can we bring the elements together to see how they work as one, illustrating how breakthrough innovators come to know.

The multi-dimensional nature of breakthrough innovators

The intuitive descriptions of T-, π- or M-shaped people carry with them the familiar appearance of spectra in the physical world, such as the spectrum of Figure 2, where the horizontal axis represents the range of wavelengths of electromagnetic waves while the vertical axis represents their intensity. An important characteristic of the electromagnetic spectrum is that each wavelength on the horizontal axis represents a sinusoidal wave that has the characteristic of being mathematically orthogonal to, and independent of, each and all of the sinusoidal waves represented by every other wavelength. As a result, the entire spectrum provides one with the ability to construct ➢







all possible waves that could exist, simply by appropriately weighting and adding the sinusoidal waves.

Applying this insight to the intuitive descriptions of the T-, π- or M-shaped people provides us with insight about the "know what" of innovation. Consider the "π-shaped" person illustrated in Figure 3 (note resemblance to the symbol, π). The horizontal axis represents the span of such a person's disciplinary knowledge and the vertical axis represents its depth. An implication of depicting expertise in this manner is that any possible collection of multidisciplinary knowledge possessed by an individual can be represented by the sum of a set of orthogonal, independent functions, one function for each entirely distinct discipline within which something is known. This is analogous to that observed with the electromagnetic spectrum, as well as to the simple two- and three-dimensional vector illustration employed in the last essay. Thus, the "know what" input of innovation, as well as the new "know what" innovative output, can be seen as comprised of a set of orthogonal and independent pieces of information.

To be clear, disciplinary knowledge is not as purely orthogonal and independent as suggested by the T-, π- or M-shaped metaphors. In fact, some overlap between disciplines is not only expected, but necessary, if only to enable communication between practitioners. Thus, the elements of "know what" that can be understood to be truly orthogonal are likely at a much lower, more granular level than at that of the discipline. Having said this, however, it is safe to suggest that some pairs of disciplines are often more significantly orthogonal (physics and literature) than others (physics and music). ■

Bruce A. Vojak is Associate Dean for Administration and an Adjunct Professor in the College of Engineering at the University of Illinois at Urbana-Champaign. Prior to joining the university in 1999 he was Director of Advanced Technology for Motorola's non-semiconductor components business; earlier he held business development and research positions at Amoco and a research position at MIT Lincoln Laboratory. In addition to his administrative responsibilities, he teaches and conducts research on the topics of innovation and strategic technology management. With Abbie Griffin and Ray Price he is co-author of Serial Innovators: How Individuals Create and Deliver Breakthrough Innovations in Mature Firms (Palo Alto: Stanford University Press, 2012). Further, he currently serves on the Board of Directors of Midtronics, Inc. and the Advisory Board of JVA Partners, as well as periodically consulting for Procter & Gamble. Bruce holds B.S., M.S. and Ph.D. degrees in Electrical Engineering from the University of Illinois at Urbana-Champaign and an MBA, with concentrations in finance and marketing, from the University of Chicago's Booth School of Business.

This essay is based on a portion of chapter 24 (*On the Epistemology of Breakthrough Innovation: The Orthogonal and Non-Linear Natures of Discovery* by Bruce A. Vojak and Raymond L. Price) of Philosophy and Engineering: Reflections on Practice, Principles and Process, Diane Michelfelder, Natasha McCarthy, David Goldberg (editors) (New York: Springer, 2013).

[i] See, for example: Franz Johansson, The Medici Effect: Breakthrough Insights at the Intersection of Ideas, Concepts, and Cultures (Cambridge, MA: Harvard Business Press, 2004) and Tim Brown, *Strategy by Design*, Fast Company 95: 52-54 (2005).

[ii] See, for example: Joseph Schumpeter, Capitalism, Socialism and Democracy (New York: Harper, 1947) and Clayton Christensen, The Innovator's Dilemma (Cambridge, MA: Harvard Business Press, 1997).

"On the Epistemology of Innovation: How Breakthrough Innovators Connect the Dots" is a series of brief, occasional essays addressed to executives, managers, and technologists responsible for innovation in industry. Its purpose is to challenge readers to reflect broadly and deeply on the practice of innovation – in particular on how innovators come to know what to do today – in order to succeed commercially in the future. Essays are available without charge at the University of Illinois' digital archive at https://www.ideals.illinois.edu/handle/2142/27667. The discussion group at http://epistemology-of-innovation.com is a place to provide feedback and dialog with the author and others regarding these essays, as well as to register to receive notice of new essays as they are issued.