Thoughts on Higher Education and Scientific Research

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The notion of a "tipping point" isn't new, although the concept has relevance in differing ways. Academia seems to be at a tipping point, whereby the steady state of disciplinary specialization is about to give way to an interdisciplinary, collaborative approach to knowledge acquisition. To understand this particular tipping point, you must first appreciate the various emergent viewpoints associated with the concept.

The Concept of a Tipping Point

Malcom Gladwell popularized the notion of tipping points in a social context in his worldwide best seller, *The Tipping Point: How Little Things Can Make a Big Difference* (Back Bay Book, 2002). The tipping point is frequently related to studies of complexity and chaos. Some liken the concept to a sand pile, to which adding one more grain triggers an avalanche. Others suspect similar consequence in the dynamics that trigger earthquakes or significant climate changes, albeit our knowledge is woefully lacking as to the true nature of these dynamics. Sociologists measure tipping points through observed changes in previously established social activity.

In physics, a tipping point occurs when an object is displaced from one equilibrium state into a new equilibrium state qualitatively dissimilar from the first. Complexity theory holds that tipping points frequently result from self-reinforcing, positive feedback loops. Here, a stable system self-generates into an unstable condition, often through amplifying oscillations. Tipping points thus reinforced can occasionally result in chaotic behavior, leading to systemic collapse.

Tipping points are related to nonlinear dynamics. Minute differences in the initial state can result in dramatic end-state changes. As a simple example, consider two roller coaster cars at rest at different positions on the track (see Figure 1). If nudged slightly, the car in Figure 1a will soon return to rest—it's at a stable equilibrium. However, if the car in Figure 1b is pushed, it will continue in motion on a wild ride—it's at an unstable equilibrium. In many systems, these states fluctuate as the peaks and valleys are often connected by the continuum of time.

Tipping points are difficult to describe using differential equations because the dramatic, sometimes instantaneous changes embody a discontinuity. In such situations, no one can predict an outcome by merely knowing the precise description of the initial state and a function that describes the causal structure of the systemic components. Rather, variables are treated as the sum of independent contributions, where results are both dynamic and contextually sensitive. As such, innovative tipping points will be relatively sparse in a world rooted in linear dynamics.

The term tipping point isn't necessarily quite as pejorative as previously suggested. A tipping point can lead to new, world-changing insights. Einstein's observations on the relationship of space, time, and the speed of light revolutionized classic physics. More recently, the discovery of long-distance relationships among subatomic particles suggests that multidimensionality and the existence

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of quanta are entirely reasonable propositions. Similarly, although many researchers have pursued the notion that chemicals may inhibit or halt the growth of cancer, a single researcher observed that cancer required its own vascular system to support growth and made strides in attacking the disease through inhibiting a tumor's blood supply. Thomas Edison made many such breakthroughs ranging from the light bulb to the phonograph to motion pictures. These inventive tipping points led to disruptive changes in the way we perceive the world and interact with our environment. Thomas Kuhn calls such tipping points "paradigm shifts."[1]

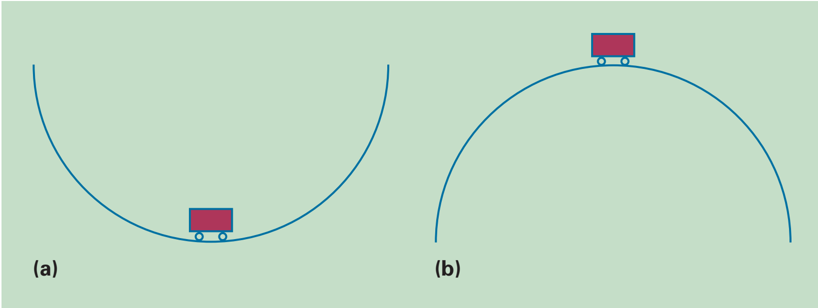

Figure 1. An example of a tipping point and its relationship to nonlinear dynamics. A roller coaster with (a) stable equilibrium and (b) unstable equilibrium.

In Search of Problems

Just as tipping points can lead to new insights, conversely, insights can become tipping points to define problems that accompany known solutions. Although it's more common to discuss the search for solutions to problems, it's equally interesting to discuss the search for problems to accompany solutions—that is, the situation where numerous solutions exist even though we don't yet know what problems they might address. These too represent introspective tipping points.

Gladwell presented an interesting example of "solutions seeking problems" in an article in *The New Yorker* ("The Treatment," 17 May 2010). He describes how a cell biologist at Harvard, Lan Bo Chen, received a US$4 million grant to study how to kill cancer cells. Chen had been puzzled by the fact that millions of chemical compounds were sitting in company vaults that had never been considered for possible medical usage. The pharmaceutical companies were only screening hundreds of thousands of these formulations, when estimates were that the world had over 10 million compounds available, most of which were developed by companies outside the pharmaceutical industry.

With his grant money in hand, Chen travel to laboratories in Russia and Ukraine that had produced thousands of these compounds. On his first trip, he purchased a batch of 22,000 compounds for approximately $10 each and brought them back to the US, not knowing if any of them might kill cancer cells. His process was simple: in his lab, a robotic arm would place a few drops of a chemical onto a plate, and then drops containing live cancer cells would be added as well as drops of blue dye. The mixture would sit for weeks. If, when reexamined, the mixture showed blue, then the cells were still alive and the compound had failed. For brevity, we'll jump to the end of his story: he did find one formulation with great promise, elesclomol, using this needle-in-the-haystack method.

The point here is that this brute-force process of working from the treatment to the disease (instead of the more traditional process of working clinically from the disease to the treatment) showed as much promise as the more rational approach. In a way, this approach forced the discovery of an important potential medical tipping point by a novel process of elimination from a universe of potential solutions.

According to Murray Gell-Mann—noted physicist, Santa Fe Institute founder, and complexity pioneer—"We need to overcome the idea, so prevalent in both academic and bureaucratic circles, that the only work worth taking seriously is highly detailed research in a specialty. We need to celebrate the equally vital contribution of those who dare take what I call 'a crude look at the whole.'"[2]

Nonlinear dynamics, with which tipping points are associated, are entirely natural and frequently occurring. They are abundant in nature, physics, geology, biology, biochemistry, epidemiology, economics, sociology, psychology, and numerous other areas of human academic study. Moreover, they're frequently cross-cutting, involving knowledge of multiple disciplines for full appreciation. They have a direct bearing to the modern notion of knowledge acquisition.

Thus armed with a background on tipping points, let's examine how they come to bear in an academic atmosphere.

Higher Education's Tipping Point

Academic specialization is highly encouraged as a means to obtain advanced degrees. Despite a growing awareness of the importance of nonlinear phenomena, much of the preparatory work in academics is done at increasing levels of abstraction in some minute area of study, without due regard to potentially relevant fields that fall outside traditional disciplinary boundaries. Thus, it's no surprise that we're producing researchers and scientists who are ill-prepared to make breakthrough discoveries.

To their detriment, academic institutions are increasingly stovepiped in highly specialized disciplinary fields, often losing touch with emergent social, cultural and natural realities. This activity, in light of recent social change and enhanced holistic understanding, foretells a coming tipping point driven by heightened realization of the inherent interconnectivity across a number of academic pursuits.

The remedy invokes both outward looking and introspective behaviors that lead to tipping points from which change will be inevitable and irreversible.

Isolation vs. Globalization

One dimension of a tipping point in higher education suggests institutions of higher education must look outward to better align with the societies they support. As the post-industrial network economy continues to integrate global interests, parochial interests—while retaining cultural significance—become secondary to broader, global issues. Some examples of the effects of these concerns include the post-industrial networking phenomena, an increasingly globally interdependent economy, and climate change. None of these persistent issues is singular, linear, or tractable in its composition.

Mark Taylor, Cluett Professor of Humanities at Williams College, argues that higher education itself is nearing a tipping point resulting from the same information and telematic technologies that led to the post-industrial economy.[3] He states that "in network culture, education becomes the currency of the realm." Education as a commodity applies both to those who provide it and those who receive it. Pragmatically, Taylor suggests that radical change might come through increasing cooperative ventures between corporate entities and institutions of higher learning, with the result being the introduction of new means to deliver education that's appropriate for emerging needs of the workplace. Without such a union, Taylor argues, existing economics can't sustain the requisite online education in the isolated university environment. Rather, he promotes the notion that universities must cease cultivating useless knowledge and learn to adapt to the changes transforming society.

The Vice Minister for Higher Education at the Ministry of Education in Ethiopia, Teshome Yizengaw, has asserted the following:

> Higher education has to constantly change and adjust to a wide variety of situations in the country, be they political, social, economic or cultural. It should not lose sight and speed and fall behind. It should not fall out of touch in relation to knowledge and the demands of the social, economic and political situations that lie outside of its walls.[4]

She further relates these mandates as essential to resolving immediate issues, such as famine, flood, civil wars, poverty, and HIV/AIDS.

Reductionism vs. Holistic Learning

Another clear dimension of the necessary tipping point in higher education is a movement from blind specialization to holistic understanding. This will require significant introspection. Academia appears to remain stubbornly rooted in the type of reductionism that grew out of the highly compartmented era of industrialization. Here, flawlessly designed interchangeable parts were the order of the day, and the notion led to a prevailingly linear, grid-like worldview.

Academia now finds itself in a vastly different era. The network era not only speaks to an increasing variety of media but also leads to custom, short-lived products. You need only appreciate the rapid transformation of handheld devices from phones into increasingly interactive computers to contemplate the societal effects of rapid technological change. The resulting diversity reinforces the type of nonlinear notions underscoring tipping points.

To remain viable in such a highly adaptive society, academia can no longer afford to "bin" topics in narrowly scoped disciplines. Rather, the holistic, multidisciplinary view becomes essential to increased understanding, to say nothing of continued relevance. The world increasingly requires integrative, cross-disciplinary vision; however, the current incentive system for academics encourages narrow, discipline-specific research. The solutions exist—they're just seeking their companion problems, which will likely manifest via societal tipping points.

Quantity vs. Quality

In addition to the narrow focus of academic research, another problem arises from the quest to publish large numbers of papers quickly, with only incremental novelty, to achieve tenure or promotion. This leads to thousands of theses and dissertations annually that offer solutions to either toy or nonexistent problems.

Several respected researchers have decried this state of academic publishing. For example, in computer science, David Parnas issued a call to "stop the numbers game."[5] Parnas objects to "measuring researchers by the number of papers they publish, rather than by the correctness, importance, real novelty, or relevance of their contributions." We agree that research should be a practical application of technology rather than a scientific formalism in a vacuum. (A further discussion of the problems of publishing for numbers and not progress appears elsewhere.[6])

Discontent with the prevailing system of scholarly publishing isn't confined to computer science. A recent article in *The Chronicle of Higher Education* condemns "the amount of redundant, inconsequential, and outright poor research."[7] Furthermore, John Ionnaidis has reported on the "increasing concern that most published research findings are false."[8]

Most critiques of the current system include suggestions for improvement, but these suggestions aren't in agreement and have yet to perceptibly change the trend toward more publications or toward papers and theses that are increasingly focused on narrow and (some would say) trivial results. This problem isn't merely one of perverse incentives in academic publishing—although that certainly is an important factor. We see the issues of scholarly writing and citation as a symptom of a deeper cause: overly specialized experts who are either unwilling or unable to see beyond their disciplinary blinders.

In the science-fiction classic, *The Voyage of the Space Beagle* (Pocket Books, 1950), A.E. Van Vogt deals exquisitely with the issue of scientific myopia. In the book, he subjects the crew of the Space Beagle to a series of challenges—ones that can't be solved by the large groups of arrogant and self-absorbed scientists in the ship's mathematics, physics, and chemistry departments. Every dilemma is eventually solved by the lone *nexialist*—the scientist who has learned how to integrate the best principles from every discipline. Perhaps we need to return to "nexialism" if we have any hope of intelligently meeting the challenges of the next century.

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