Commentary: The benefits of being a maverick FREE

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The benefits of being a maverick

Paradigm shifts start with revolutionary ideas. Thomas Kuhn, one of the most influential philosophers of the 20th century, coined the term "paradigm" as an agreed-upon state of knowledge and then went on to describe how that state is ruined as exceptions accumulate. In Kuhn's model,[1] emerging exceptions lead to the replacement of old paradigms with new ones, and as a result, knowledge leaps forward and progress is made. It is a process driven by mavericks and stemming from dissent.

THE PHILOSOPHER ANAXAGORAS, by Giovanni Battista Langetti, oil on canvas (c. 1660), Philadelphia Museum of Art. (Purchased with the W. P. Wilstach Fund, 1904/public domain.)

Dissent as part of the process

In science, dissent is not a drawback; it is a necessity. The mathematicians Edward Kasner and James Newman write that "the testament of science is so continuously in a flux that the heresy of yesterday is the gospel of today and the fundamentalism of tomorrow."[2] The courage to say no to scientific authority, to contradict widely accepted knowledge, to question and disrupt the status quo is essential to science's ability to move forward.

In a 1675 letter to Robert Hooke, Isaac Newton wrote the famous phrase "If I have seen further it is by standing on the shoulders of Giants." Newton paraphrased earlier uses of that sentence to make a point: Mavericks can produce transformative change only thanks to a vast body of incremental research done quietly, with no fame or recognition, and with no front-page news. In science, the incremental progress of many enables the transformative actions of individual mavericks.

And the history of science is rife with outstanding mavericks. In the fifth century BCE, the Greek philosopher Anaxagoras suggested heavenly bodies are made of stones snatched by a rotating ether. Arrested and sentenced to death for his claims about the Moon and the Sun, Anaxagoras was saved by his friend Pericles, a powerful statesman, and instead was exiled. The revolutionary progress made by Anaxagoras spurred some of humanity's earliest attempts at understanding the order of the universe and the transition from chaos to order through motion, an idea still in use today.

Nearly two millennia later, a different paradigm described Earth as a motionless object in the center of the universe. The work of Nicolaus Copernicus (1473–1543), embraced by Giordano Bruno (1548–1600) and supported by Galileo Galilei (1564–1642), provided a new "heliocentric," or Sun-centric, theory, backed up by hard evidence showing that the Sun is in the center of our solar system and Earth is one of the planets orbiting it. (See the article by Mano Singham, PHYSICS TODAY, December 2007, page 48.)

Such dissent is not exclusive to the early days of science. Scientists previously believed continents were unmoving bodies. Then to explain the matching large-scale features and outlines of separate continents, in 1912 Alfred Wegener (1880–1930) suggested that continents are, in fact, moving.[3] His claim, introducing plate tectonics to geology, was met with ridicule and hostility. Wegener was seen as proposing a "footloose" hypothesis that took "considerable liberty with our globe," as the prominent geologist Rollin T. Chamberlin of the University of Chicago wrote.[4] Despite the ridicule, Wegener's findings helped pave the way for modern geoscience.

The role of quantum mavericks

That trend continues. David Wick expertly describes a similar situation in his book *The Infamous Boundary: Seven Decades of Heresy in Quantum Physics* (1995). The prominent leaders of the field, such as Albert Einstein, refused to accept quantum theory in its entirety. Interestingly, one can find dissent, or at least strong polarization of opinions, in quantum physics almost continuously from the early 20th century to the present.

A good example is the surprising lack of a consensus—or fundamental understanding—of quantum mechanics. Among the currently discussed and often mutually exclusive interpretations of quantum mechanics that one can find are the Copenhagen, many-worlds, hidden-variable, spontaneous-collapse, informational, relational, and transactional interpretations, along with many others. Sessions on the topic at annual meetings of the American Physical Society are among the most attended, and they always lead to fascinating disputes and sometimes to heated debates. While debates about fundamentals continue, new areas of dissent are born, as scientists discuss answers to such questions as "Can we build a fully functional quantum computer that demonstrates an advantage over a classical one?" and "Can we use topological properties to build such a quantum computer?"

In the field, the coexistence of dissent and actual transformative progress is second to none. That excitement continues today, and it is fascinating to watch its overarching societal consequences, including the 2018 passing of the National Quantum Initiative Act; the fostering of quantum information science and engineering research; and the rise of the second quantum revolution, which targets the creation of quantum technology. Born out of—and continuously generating—dissent, coordinated by collaborative efforts, and enriched by the incremental work of many, the paradigm breaking and ongoing race in fundamental quantum research may one day change our lives the same way semiconductors have.

Paradigm-breaking revisited

The mavericks in the history of science may have paid their price, but they also provided necessary, transformative, and disruptive leaps in the progress of science. We owe them a debt of gratitude. We also owe such debt to their adherents, who explored the details of novel theories, filled the holes in reasoning, and pushed the boundaries of knowledge forward through the hard daily work of incremental research, which paved the way for the next great disrupters.

There is more to this story. Perhaps to improve the way we do science, we could find a way to break the paradigm of paradigm breaking and make better use of brilliant minds. Avoid the drama, use scarce resources wisely, and accelerate progress by coupling collaborative efforts with risky transformative ideas. Leadership in science and technology depends on the broad acceptance of risk and on our ability to elevate paradigm breaking to the norm.

Steps forward

Three steps are necessary to achieve such leadership: Create sustainable conditions for fundamental research that fuels translation into applications, accept scientific dissent and high risk, and embrace diversity.

On the tree of discovery, fundamental research forms the roots, and translation is the sweet fruit. We know beyond reasonable doubt that without fundamentals, characterized by lack of immediate application, there simply cannot be future applications. Examples of such a connection abound, including the transistor, the internet, and the smartphone. In a healthy science and engineering ecosystem, expanding and accelerating translational efforts is coupled with a careful and proportional treatment of fundamental and applied research.

Acceptance of risk is already practiced by several government agencies, including NSF, where I work and where the concept of high-risk, high-reward projects is openly embraced. Risk is difficult to assess, yet a discussion of what constitutes risk within a given structure is always the starting point, alongside identifying and selecting projects of high transformative potential while maintaining the ability to fund necessary incremental progress. It is a fine and complex balance that is under constant and careful adjustment.

The addition of a focus on diversity elevates the other two steps. Diversity is the source of rich, vibrant, and fruitful discussion, a cornerstone of modern science. Only through bringing together and connecting researchers from different backgrounds, cultures, disciplines, and views can we make progress. There is a tremendous and heavily underutilized potential residing in institutions that host groups historically underrepresented in the science workforce.[5] Such groups require and deserve well-planned and sustained support.

In the past, society would punish mavericks, only to later reap the benefits of their paradigm-breaking discoveries. In the future, we may choose to accept dissent, risk, diversity, and balance and thus nurture an army of mavericks to lead the way. The best time to break Kuhn's paradigm of paradigm breaking may be now.

Disclaimer: Any opinions, findings, and conclusions or recommendations expressed in this commentary are those of the author and do not necessarily reflect the views of NSF.

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