The Value of Not Knowing in the Progress of Science: A Revision to Kuhn on Why Revolutions in Science Must Happen

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ABSTRACT: Why do scientific revolutions occur? Not chiefly because of accumulated anomalies, as Kuhn originally suggested. Rather, it is because scientists each must start from scratch. If a paradigm remains successful long enough, newcomers to the field will take more time than they can afford to get up to speed. If a new paradigm jettisons much former knowledge, it will seem increasingly attractive. While advances in the old paradigm require high levels of experience and sophistication even to understand, the new is replete with low-hanging fruit.

"In the thirties, under the demoralizing influence of quantum-theoretic perturbation theory, the mathematics required of a theoretical physicist was reduced to a rudimentary knowledge of the Latin and Greek alphabets."

— R. Jost, quoted in Streater and Wightman

"Ignorance is bliss"

— old proverb

1. **Introduction**

It has been half a century since Thomas Kuhn's (1996) brilliant work revolutionized the study of scientific revolutions and, indeed, that of science itself. I will have occasion to argue below why his basic notion of paradigms and their shifts is still the right way to consider scientific progress. But the main point of this paper is to suggest revisions to his views of why paradigms change, and indirectly what these revolutions imply about the nature of the scientific enterprise.

Originally, Kuhn suggested that the usual reason for a revolution is that, through the workings of normal, problem-solving science based on a particular paradigm, eventually anomalies proliferate and the field is thrown into crisis. Occasionally the crisis can be resolved within the paradigm, but at other times, a rival paradigm comes into being that deals more fruitfully with the crisis, and the old paradigm loses out. Because (or at least the version of history that apprentice scientists learn from textbooks) is written by the winners – in effect, a whig version of history — science seems continually to progress, even though, in actuality, the new paradigm renders irrelevant (incommensurable) much of the learning that accrued through the old. If revolutions are essential to science, then, it is not the simple accumulation of knowledge that characterizes it, but rather increasing learning offset by occasional— though partial — bouts of forgetting.

To me, this institutionalized forgetting or the individual ignorance that underlies it is more essential than Kuhn posited. This view emerges from a critical assessment of his explanation of crises and their role in paradigm shift. As Kuhn himself argues, a crisis cannot really take hold unless some new paradigm is already in competition with an old one. Until then anomalies can simply be tolerated or ignored, on the assumption that they simply represent normal problems that are more tricky to resolve than has yet been understood, and that solutions will turn up without the need for revolution. As many commenters on Kuhn have long noted, and he himself eventually accepted, the history of science is replete with anomalies that in some cases have lasted and grown in number through more than one paradigm without ever being addressed and without causing crises. But if new paradigms do not arise directly from the accumulation of anomalies, why are they introduced? I suggest that they in fact emerge for quite another reason, which, as far as I am aware has been overlooked both by Kuhn and by others. This reason comes into view when we consider more carefully how scientific progress works.

2 What is scientific progress?

Kuhn (1996, 161) points out that there is almost a circular relation between the notion of progress in a field and its mark as a science, that, for instance, Western European painting during the Renaissance and after could be considered a science because it accumulated a

series of methods that seemingly allowed greater and greater realism. Only, says he, when this art departed from the goal of greater realism did it lose any claim to be a science.[1] Within a paradigm, science consists of the accumulation of solved problems as well as general techniques and theories that can be applied to solve still more problems. For the scientists operating within the paradigm, the existence of such progress is taken to be a clear sign of heading towards greater truth. When the paradigm is replaced, however, much of this progress begins to seem like error.

Still, though Kuhn does not state this, apparently there are some paradigm-independent methods of gauging scientific progress, today including the number of peer-reviewed papers published in respected journals. A net increase in these, per period, in some sense must be viewed as progress. This is so even though within a paradigm not all papers achieve equal status. For each, a simple way of gauging such status is by the number of subsequent citations it receives, especially when compared with other papers published at roughly the same time. Presumably those papers with the most citations are particular founts of progress.

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[1] Kuhn doesn't specify when the goal of greater realism in art ended. Could it have been as early as the rise of mannerism in the sixteenth century? Danto (1997, 3-17) while not referring to art as a science sees progress in art (a master narrative) continuing until the late twentieth century, through what might be called a series of paradigm shifts.

If not all papers are equal, neither are all researchers. An individual scientist is likely to do best if she is good at producing results that receive large numbers of citations. For one thing, such success will mean that other scientists are following along in her wake. For another it very likely will mean that she will be successful at obtaining grants, good positions for herself and her students, and possibly even prizes, all of which serve to help strengthen the paradigm in which that scientist works.

Individual success in producing highly-cited results is thus both necessary for overall progress and shapes its direction. It doesn't much matter whether an individual practitioner is interested in such success or not, or is consciously competitive or not. Progress cannot occur without individuals being able to excel at publication and at drawing attention to what they have done, however they happen to achieve this, or with whatever intent.

3. The Value of Not Knowing

Consider then a graduate student in a field with a longstanding dominant and highly successful paradigm. The greater the success of the paradigm, the more the new entrant must learn in order to be able to operate at the forefront of research. Inevitably, such a situation will undercut the student's ability to make a mark. In principle, the years of preparation required could eventually be too long for a normal lifetime. Well before that, new students, seeing the near-endless trail ahead, will be discouraged from entering the field. Quite

possibly as well, from the viewpoint of a newcomer the problems that need further elucidation will seem less exciting than those of some other, less developed paradigm.

A brand new paradigm or even the first bits and pieces of an emerging one can be exceptionally attractive to new entrants because it might require minimal learning to be able to make striking new contributions. Every such contribution in turn will help recruit still more newcomers, new converts from the old paradigm, or even researchers brought up in quite different fields. Though they will have to get comfortable in a "new world," as Kuhn puts it, they will be able to ignore much of the accumulated lore, facts, techniques and theories of the paradigm their work displaces. What they ignore will begin to seem to them clearly nonsensical, baroquely abstruse, and utterly unnecessary error.

Of course, along with the advantages accruing to followers of the new paradigm might come some difficulties. For one thing, existing faculties, grant makers, editorial boards and the stables of referees they tend to draw on for making publication decisions will usually be dominated by followers of the well-established paradigm. Still, a sufficiently striking and impressive new one — promising much in the way of ripe, low-hanging fruit — is likely to overcome these obstacles. To change metaphor, scientific institutions are not unassailable fortresses; a variety of paths ranging from informal seminars, individually circulated papers in advance of publication, “bulletin board” sessions at conferences, or even press conferences touting surprising new results all allow instigators of new paradigms or their early recruits a chance at gaining more followers. And some referees or other gate-keepers may be open-minded enough to entertain views that most of their colleagues might think should be kept beyond the pale.

4. An example of a failed new paradigm

Another problem is of course that the revolution may fail: A very new paradigm or an emerging one, however striking, may not lead to tenable results and simply fall apart. The case of cold fusion provides an example. It was announced by chemists, to enormous publicity, thus evading the usual guardians of the standard paradigm of nuclear fusion, controlled up to that point by nuclear and plasma physicists. (According to Kuhn's views, the field might well have been in crisis; many years of confident research in controlled nuclear fusion had been unavailing, but in practice the problems had been — and still are being — ascribed to detailed unforeseen but superficial problems with the methods that had been so confidently tried.) The "discoverers" of cold fusion exhibited minimal conversance with the dominant paradigm, which required energies far larger than chemical to overcome electric repulsion between the nuclei that were to fuse. Physicists generally ridiculed the claims, but since the methods were so easy to replicate, both physicists and chemists attempted to. Physicists tended to reported the results could not be duplicated, but a number of chemists persisted for years, claiming repeated success. Eventually, however, cold fusion has lost most of its followers.

5.Success

In similar situations, however, new approaches often do succeed. Kuhn himself cites a notable example of an outsider blundering into a field and revolutionizing it: John Dalton making his entrance into the field of chemistry with his atomic theory. More recent examples include the phage group introducing physics ideas into the basis of biology, the introduction of PET scans into functional neuro-biology, the introduction of inflationary theories into the field of cosmogony, the equation of birds with dinosaurs, the development of information theory and its use in the theory of entropy, or even the development of completely new fields such as complexity theory.

In all these cases and many others, only very limited prior knowledge was enough to allow new entrants to come up with results on the frontiers of knowledge, results that furthermore could immediately be seen as striking by a large number of not specially trained outsiders. This was enough to draw in still further recruits as well as funding, newly opened faculty positions, etc. In addition, many of the important contributors can be unusually young: Wolfgang Pauli was just twenty-one when he published the *Encyclopädie der mathematischen Wissenschaften* article that, reprinted, became the first textbook on special and general relativity; he, Heisenberg, Dirac and others were in their early twenties when they made key contributions to quantum mechanics. Watson was just 23 when he and Crick, a refugee from physics, proposed their model.

6. The necessity of gaining attention

To say a result is striking is only to say it draws wide attention. To some degree, a genuinely new paradigm by itself is quite likely to have this effect, simply because, as Kuhn rightly puts it, it opens up a new world. Still, it will help if the originators or early adopters include quite talented and/or eccentric writers and speakers. Einstein was certainly gifted in both these ways. So too was Darwin. Yet another sort of attention getting is needed if the new paradigm is to draw new recruits, as it must if it is to succeed. It must make evident that there await plenty of results ripe for the picking by whoever ventures into this new orchard, and that it is also an orchard easy to cross into with a minimum of required preliminaries.

7. Can revolutions not occur?

It might be posited that there exists another way to deal with too much knowledge within a successful paradigm. Couldn't it divide into sub-specialties, with still further branchings to be expected when the subspecialties themselves accumulate further knowledge? In principle, it might seem, such developments could continue indefinitely, with no loss of knowledge and no new paradigm. Kuhn's view of "normal science" seems to give support to such a possibility, since he emphasizes that problems seen as important within a paradigm will be understood as such only by its relatively small group of specialized practitioners. But what would be the path of entry into such a sub-sub specialty? If it is still seen as connected to a larger field, in the principles of which new entrants must be inculcated, the problem of too much to learn would still arise, unless what had been the overall paradigm had been subject to revolution of its own. In that case the sub-sub-specialty in question would be increasingly

divorced from the rest of the field, unable to draw either new recruits nor new ideas from the surrounding sub paradigms without being invaded by revolutionary ideas. An old example of this is astrology, no longer considered a science and entry into which no longer coincides with entry to other branches of astronomy.

One of the strengths of Kuhn's paradigm notion is that each paradigm is held and developed by an interacting community of practitioners. Each such community must have relations with other such communities, so that one can loosely speak of a scientific community as a whole, a community all of whose members give respect to neighboring and even distant successful paradigms and often draw on them. A paradigm and its community without such external relations might continue, but not as science, from which community it would be effectively exiled. Just as practitioners of "creation science" or astrology are not likely to be allowed to form their own departments within the science faculties of major universities or as separate sections within major broad-ranging scientific societies such as the AAAS or the British Association, a paradigm community that fails to undergo a revolution for too long a time is likely to find itself excluded if it has found the means to survive at all.

If I am correct then, revolutions are both inevitable and necessary if science is to continue to progress. Steven Weinberg, among others, has dreamt of "a final theory." The very term suggests stasis, which in the practice of science must mean decay. What will prevent that is new people entering the field and coming up with something that seems to them worth doing. As long as that continues the social process that is science will have to involve endless revolution.

8. Can what was forgotten be regained?

It will remain true that publications themselves will continue to accumulate, at least as potential historical records. Historians of science will in some cases be partially able to trace the internal logic of older, mostly forgotten paradigms, and occasionally such efforts might even end up affecting new scientific efforts. But any reclaiming what has been forgotten will be partial at best. Just as we can never be certain what, say, medieval music sounded like, we can never be certain of the correctness of reconstructions of past tacit knowledge, once handed down from mentor to apprentice over a period of years. Science historians are unlikely to be so numerous that they can restore, even partially, more than a small amount of lost scientific knowledge, while if they should be numerous enough, the knowledge they've regained will be partially lost again as their ranks are augmented with newer scholars.

9. Some closing reflections

As Kuhn made clear, and the view expressed here requires, science is not and cannot be a system converging on ultimate and final truth, but rather a system of incremental progress along paths in ever-changing direction. Just as any finite set of data points can be represented by infinitely many mathematical functions, any finite subset of scientific facts held to be valid according to one paradigm at a specific moment in history can be fitted into a very large number of conceivable, if possibly outlandish-seeming new paradigms. A new one that wins out over an established one will have to show itself quickly capable in terms of the context at

the moment to lead to new and significant results. In so doing it will redefine the direction that counts as progress — much like Brownian motion in a space of many dimensions. The new paradigm will once again seem to its practitioners as they are working in it to be heading towards greater — if not final — truth.

Is the process of paradigm change proposed here to be viewed as internal to the relationship of scientific knowledge to the world, or as external to it, a result merely of human limits or of social relations within science? My answer: both. Science is a particular sort of institutionalized pursuit, a social process of obtaining and valorizing knowledge that can have no real meaning divorced from that process, a process carried on only by human beings. Thus, the explanation I offer of paradigm shifts, if it has anything to do with reality, must hold for the future as well as the past of scientific knowledge, and thus of the truth as understood in any time frame.

Before modern science, and alongside it, there have of course been other modes of gaining and valorizing knowledge of various kinds, even knowledge of the so-called external world, for instance creation myths and their more specifically religious retellings. It is possible of course that in the future some new way of doing this for areas that overlap with what we call scientific practice will come to replace the particular institutional form that has characterized science for the past few centuries. Such a new form may not require individual human learning and thus no equivalent to textbooks, graduate studies, success in publication, and the like. Conceivably, this new form might not require or even have openings for paradigm shifts. I for one have no idea how such a system would operate or what it might

entail, but if it does come into existence it would probably be so different from anything we are used to as not to be usefully termed science at all.

In our science, on the other hand, progress towards apparent truth occurs both within paradigms and through the revolutions that mark paradigm shift. Were there no paradigms — in the sense of community held common understandings of theories, of how to relate them to observations, of how to make observations, of which of these are important, as well as of pressing problems — then there could be no agreed upon progress and hence no science.

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