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Review:

Science as Reflective Practice: A Review of Frederick Grinnell's Book, *Everyday Practice of Science*

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Frederick Grinnell, a professor of cell biology, has written about the practice of science. I was introduced to his writings first through his article, "The Practice of Science at the Edge of Knowledge," published in *The Chronicle of Higher Education* (Grinnell, 2000). Later, I found his homepage, which contains two sections: (a) "doing science" and (b) "reflecting on what doing science means." It is the spirit of the second section that persuaded me to read more from Grinnell. In *Everyday Practice of Science*, Grinnell presents us with an account of what doing science means to him, written from the standpoint of a practising scientist. In this review, I try to identify the author's notion of *everyday practice of science* and link it with what I consider to be the broader notion of *research practice*.

The book presents yet another critique of the so-called "linear model of science." According to the linear model:

> Researchers observe and collect facts about the world.
> Researchers use the scientific method to make discoveries.
> Researchers are dispassionate and objective observers. (p. 188, all page numbers are from Grinnell, 2009, the book under review)

Sustained work in history and philosophy of science, sociology of knowledge, and science and technology studies has contributed a lot to our contemporary understanding of science. Observing real scientists working in their laboratories has given us a picture of how scientific facts are constructed in laboratory interactions (Latour & Woolgar, 1979). The news that the linear model does not represent how scientists actually work should not surprise us.

Still, what makes Frederick Grinnell's book interesting is that it belongs to an important writing genre: researchers reflecting on the nature and meaning of their own work. This kind of writing affords an insider view, a view to which researchers working in different disciplines and fields may relate, leading to the possibility of an open discourse about research practice in all its diversity.

I approach this review task with the following question: How does the book contribute to an open discourse about research practice?

1. Topics Covered

The book is structured in two parts (Part I: Science and Part II: Science and Society). Part I presents an insider view of the everyday practice of science, highlighting two interactive processes: "the circle of discovery" (said to be a conversation with the world to be studied) and "the circle of credibility" (said to be a conversation with the other members of the scientific community). A picture of two interacting circles captures the idea (Figure 1.1, p. 5). A detailed examination of these interactive processes reveals the ambiguities, uncertainties, and conflicts that are inevitably involved in the practice of science. Part II concerns itself with the broader social environment of science and how that environment influences the work of scientists. It delves into two sets of issues: those of ethics and values in scientific research.

Going further, I present a glimpse of the book's contents. Then, in Section 2, I focus on the review question, looking for the book's contribution to an open discourse about research practice, identifying a number of relevant topics not covered in the book. Finally, in Section 3, I join what I consider the book's main cause, to make a case for promoting this particular writing genre, that is, reflective accounts of practice written by researchers, and promoting the use of such accounts as learning material for research education.

1.1. What the Scientific Text Conceals

The author cautions us against the oversimplified picture of science we get from textbooks and research articles: "textbooks usually present facts without clarifying where and how they arise. . . . The consequence is that practice becomes invisible" (p. 6). Scientific research articles are hardly different; they tend to be logically structured announcements of some results rather than a report on the exact details of what went behind. For example, the author reminds us, experimental failures are rarely reported.

However, in the everyday practice of science, "one encounters an ambiguous world demanding risky choices" (p. 14). A scientist setting out to study some system has, at best, a hazy understanding of it. Nevertheless, experiments have to be set up to test clear-enough hypotheses. Consequently, even the most elegantly designed experiments bring about unexpected results. An alert experimenter may notice some of these unexpected results and that may lead to interesting discoveries. The pathways to scientific discovery pass through many a diversion, often prompted by unexpected results and risky choices at several critical junctures in the research process.

In a vast range of scientific texts, these nebulous moments of science are concealed under a narrative of certainty and precision. Of course, this particular narrative convention in science serves a purpose: that of linking an individual scientist or research group with the broader scientific community. The convention seems to have grown around the need to provide just enough information for another scientist, working in another laboratory, to try out the same experiment, to test the claims made by the original scientists who is announcing the results. A fundamental misunderstanding about the practice of science arises when one mistakes the scientific research article to be a true record of the work that went behind (p. 8).

Similarly, in practice, the dividing line between the so-called basic and applied research proves difficult to identify. The movement of scientific ideas tend to be intertwined with the ongoing refinement of the instruments and tools used in science, each feeding on the other (p. 56).

1.2. Uncertainties and Ambiguities

The everyday work of a scientific researcher is not as systematic and straightforward as the scientific literature may suggest. Both the process of arriving at significant scientific results and the process of establishing credibility of the result in the relevant scientific community are replete with uncertainties and ambiguities. Many scientific experiments are inconclusive or uninterpretable: "10 research notebooks' worth of experiments might be required to publish a 10-page research paper" (p. 21), implying that a reportable story is often constructed out of a veritable maze of assumptions, intuitions, actions, observations, experiences, surprises, and reflections--of course, choosing only those elements that may cohere as an acceptable scientific report.

The direction of inquiry in any scientific research project is a resultant of various factors impinging on the everyday practice of science from many different directions. Working at the twilight zone between the known and the unknown, scientists have to depend on their knowledge, experience, as well as intuition, to distinguish between "data" and "noise." What may seem as noise, and may thus be ignored, could open up new lines of inquiry if a researcher notices something unusual in it and decides to explore it further. "Being prepared to notice the unexpected often is the key" (p. 28). However, research settings usually resemble small businesses, notes the author, where resource limitations can constrain the scope of work. Investing in one project implies that something else will not be pursued (p. 35).

One particular type of uncertainty arises in studies where observations about individual cases must be used to arrive at conclusions about the population to which they are considered to belong. This is the case in biomedical research, as in many other fields too. When a disconfirming evidence is found at an individual level, does it falsify a population-based conclusion? It may not, if the individual case is treated as an exception, or if the case is attributed to a possible subpopulation yet to be identified (p. 39). Moments like this may be seen as corresponding to forks in the path of research, where the direction and focus of inquiry would depend upon the choices made by a researcher.

New results from research, which must be presented to the wider scientific community in order to gain credibility, may or may not be received well depending upon the prevailing "thought style" (p. 46). Any result inconsistent with the prevailing thought style would encounter some indifference, even resistance, in the scientific community. Of course, thought styles do change over time.

Illustrating the idea in the field of biomedical research, the author identifies the changing thought style in terms of how the broad focus of research in this field has evolved over time. At the early stage of development of this field were the "microbe hunters," after which came the "vitamin hunters," "enzyme hunters," and finally the "gene hunters" (p. 49).

Thought styles prevailing within a scientific field influence the choice of topics considered worthy of investigation. However, researchers faced with unexpected observations or new experiences may question the thought style. One who has not yet acquired a huge stake in a particular thought style is likely to question it more readily than the one who has acquired such a stake. "Most researchers do their most creative work toward the early part of their careers" (p. 55), because the stakes are still small. Also, working with new tools, trainees, and collaborators increases the chance that a thought style maybe challenged.

Sometimes credibility comes soon after a result is announced; sometimes it can take years (even decades). To continue one's line of research even when credibility is not forthcoming, poses a dilemma for the scientist. On the one hand, the line of research may be fundamentally flawed and credibility will never come; on the other hand, the line of research may be valid and credibility may come in time. There is little to guide a practising scientist other than one's own intuition and passion, and the optimism that the prevailing thought style may change.

In some cases, a line of research may or may not be pursued depending upon the availability of research grants. Research grant proposals follow a credibility process that is different from that of research results. Grants maybe approved depending upon how the grant reviewers assess the importance of the research question posed in the proposal and the capacity of the grant seekers to answer that question adequately, provided of course that the proposal falls within the research priorities defined by the funding agency (p. 80).

These uncertainties and ambiguities in scientific practice make it remarkably different from the simple linear view. The author then goes on to unravel another layer of intricacy associated with scientific practice, involving issues of ethics and values.

1.3. Ethics and Values

Additional intricacy in scientific practice arises from the institutional and social context of scientific work. Since the emergence of large-scale science involving huge sums of public money, and occasionally producing undesirable consequences, scientific work has come under the gaze of regulatory agencies around the world. However, regulation of scientific research has not been easy, particularly because of the uncertain nature of the process and the potential conflicts of interest between individual scientists, within scientific research groups, and between scientific and nonscientific establishments. The author traces the history of regulation of science and describes the difficulties associated with different approaches to regulation adopted over the years.

Whether a research project is worth funding or not has proved to be a complex question for regulatory agencies. Often left with no objective way to answer this, agencies have set up expert panels to advise on research proposals. This approach remains vulnerable to the vagaries of competitive behaviour among scientists and research groups, also to the influence of interest groups such as business and industry (p. 103).

Once funded, there is also a need to monitor progress. This has not been easy either. Both funding agencies and managers in research laboratories have found it difficult to define efficiency and productivity in science: completing a specific project within the prescribed time and resource limits is as important as allowing the trainee scientists to make mistakes so that they may learn (p. 111). Scientific work pursues multiple goals. By recognising these multiple goals, argues the author, science policy could become more realistic.

Both scientific institutions and public agencies have grappled with the issue of scientific misconduct. Cases of betrayal of trust, fabrication of data, and plagiarism have surfaced from time to time. Again, it has proven rather difficult to establish clear-cut principles to decide on such matters (p. 115). Given the ambiguity between data and noise, there is a very thin line between fabrication of data and intuitive selection of meaningful data by an expert scientist. Regulatory agencies face the dual challenge of maintaining standards of scientific practice while ensuring that the standards do not stifle innovation and risk taking by scientists.

A rather contested area is that of intellectual property. The principle underlying the idea of protecting intellectual property does not find universal acceptance among scientists. The author cites one of the founding fathers of modern science, Benjamin Franklin, who opposed patenting of inventions (p. 122). Those who support such protection however, argue that it would incentivise innovation and promote investment in scientific research. Implementation of intellectual property protection has spawned the “patent and prosper” regime among scientists and engendered a business model for the research university.

Whether it has really served the cause of research and innovation is difficult to argue, but it has certainly led to numerous patent disputes. Besides, when research is backed by business houses, there can be a variety of distortions introduced into research, including insufficient protection of human subjects involved in the research. The people who assume the greater risks of research are often not the people who stand to benefit the most.

Finally, the author explores the complementarity between science and religion, putting forward the proposition that "science and religion represent distinct human attitudes towards experience" (p. 161). The complementarity arises because both science and religion respond to intellectual curiosity in the face of new experiences. Both provide ways by which one can compare one's experiences with those of others. Both require humility, accepting the limitations of our understanding. In the face of global problems such as poverty, disease, and environmental degradation, the author remains hopeful about the coming together of science and religion: "Perhaps solving global problems will require the scientific *and* religious attitudes--both types of faith--rather than one or the other" (p. 185).

2. Topics not Covered

2.1. Different Forms of Inquiry

Grinnell speaks of science as the search for the "physical mechanisms of the world" (p. 13), which the scientist must work out without knowing for sure "where the object has been hidden" (p. 37). These metaphors do not apply equally to all branches of science, let alone other forms of inquiry, for example, in the arts and humanities. The book conflates laboratory-based experimental science with science or inquiry in general. How do the book's arguments relate to different forms inquiry, other than experimental science?

Some of the arguments appear relevant over a wider range of research practice. Research in any domain encounters ambiguities and uncertainties, comparable with what Grinnell describes in the book. Just as the experimental method involves ambiguities and uncertainties, so do the other methods of inquiry, such as ethnography, historiography, hermeneutics, mathematical modelling, computer simulation, critical design, interaction design, and so forth. In fact, one basic uncertainty researchers outside experimental science face is in selecting an appropriate method of inquiry in the first place (e.g., Probert, 2006), that is sometimes resolved by selecting a "mixed" method (Mingers & Brocklesby, 1997; Vakkayil, 2007). This issue receives little attention in the book because of the restricted image of science adopted.

Similarly, the issues of ethics and values also arise in any other form of inquiry so long as the process occurs within human settings--both institutional and social. Specifying and adhering to ethical norms appear quite challenging in certain forms of inquiry which involve some manoeuvring around human feelings, identities, rights, relationships, spaces, traditions, and so forth. The book's limited exposition of the ethical issues in science again reflects the restricted conception of science adopted. Consequently, what

Churchman called the "deeper problem of morality" in the process of inquiry (Churchman, 1968/1979) does not receive any attention in the book.

2.2. Role of Science, Scientists, and Citizens

The debatable nature of scientific expertise, as discussed in the broader discourse concerning science and society (e.g., Wachbroit, 1999), is not explored adequately in the book. Given the ambiguities and ethical issues in the practice of science, what ought to be the role of science (and scientists) in matters of public concern? Dealing with this question, Wachbroit suggests, for example, four modes of public engagement: (a) *technocratic* (where scientific expertise defines the limits to what can or cannot be decided through public deliberation), (b) *adversarial* (where experts provide support for the positions of various parties engaged in that deliberation), (c) *participatory* (where views of experts and knowledgeable non-experts can be brought into the public sphere and contested), and (d) *zero mode* (where experts have no special status). Grinnell does expect scientists to play a role in dealing with some of the global problems of our times, but he does not clarify the exact nature of that role.

Regarding the complementarity between science and religion, the book opens up a complex topic without equipping the reader sufficiently to deal with that complexity. The level of precision achieved in the description of experimental science is missing in the description of religion. Religion has been interpreted following William James, as the "belief that there is an unseen order, and that our supreme good lies in harmoniously adjusting ourselves thereto" (p. 163). Somehow, this particular description sounds more scientific than religious to this reviewer. It calls to mind research topics in public administration or urban planning (e.g., how to achieve efficient public service or how to build safe cities --"efficient public service" and "safe cities" being examples of the unseen order).

It seems, the global problems Grinnell considers important (namely poverty, disease, and environmental degradation) require an extension to what he means by science. Working with his restricted notion of experimental science, Grinnell recognises that "[t]he features that make each person unique and special from a humanistic point of view can confound scientific research" (p. 134). Of course, it may confound the kind of research that requires certain commonalities across all persons (as does cell biology). What Grinnell does not recognise is the possibility of reframing his idea of science to accommodate the humanistic point of view, for example, to find effective means to enable unique persons to collaborate and overcome some of their collective challenges?

Ways of enabling individual persons has indeed been the focus of some scholars dealing with the issue of practising scientific and professional expertise within civil society. Rather than placing citizens in a situation of incompetence, professional practice can be adapted to recognise the legitimate spheres of competence of both the citizen and the expert (e.g., Ulrich, 2000). Ulrich offers, for example, a framework for reflective professional practice that is based on the civil competency, he calls, *critically systemic thinking*. This is a competency that all citizens can develop--experts and nonexperts alike.

The traditional image of science is not adequate to discuss the whole gamut of issues relating to science in society. Interesting examples of reframing the idea of science can be found in many domains. It need not always be about discovering "physical mechanisms of the world" as Grinnell states (p. 13). Different forms of inquiry can be bred, that differ from each other in terms of what they take as their "world" and the "mechanisms" that generate the world (Zeeuw, 2001). Experimental science would then be just one of these breeds, sharing with the other breeds a key family resemblance, that is, the open-ended quest for quality Grinnell has so vividly described in this book.

3. Research Education

Despite the shortcomings mentioned above, the book's campaign against the linear model of science is rather vibrant and forceful. Given the pervasiveness of the linear model, the book's message is quite valuable, particularly as it captures some authentic reflections of a practising scientist.

The book provides useful learning material for every researcher (not only scientists). It represents an important genre of research writing, which contains self-reflective accounts of a researcher's work, targeted at peer researchers anywhere, even beyond the boundaries of one's own field. As such, it demonstrates two things: (a) there is something to talk about (i.e., arising out of one's engagement with research in some field) and (b) there is a way to talk about it (i.e., one can choose a form of narrative to convey one's research experiences and quandaries even to nonexperts).

There is something to be said about the importance of such writings for *research education*. Currently, there are two major sources of learning material for the beginner research student: text books on research methods and articles published in scholarly journals. Unfortunately, both of these seem to be founded upon the so-called linear model. There is a dire need for learning material that would help research students acquire a familiarity with the real world of research. Such material exists in the domains of history of science, sociology of knowledge, and science and technology studies. However, these have grown as specialist fields and sometimes the literature seems to be targeted at specialist readers. In this context, Grinnell's book provides an example of another type of learning material. Insider accounts of research such as this serve to foreground the high adventure of research and the passion of researchers. Reading such material can support research education in a special way, by promoting an understanding of research as a process of critical engagement with thought styles, of one's own and of the others, within the overarching ethic of humility.

As for the more advanced task of research education, that is, to enable researchers to breed and nurture different forms of inquiry, one needs to look elsewhere.

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