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REPORTS AND REFLECTIONS

Learning Sciences Research and Pasteur's Quadrant

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Learning scientists often use Donald Stokes's influential characterization of the relation between basic and applied research in his book *Pasteur's Quadrant* to suggest that most of the work in the learning sciences lies, or should lie, at the intersection of both types of research, that is, in the cell that is epitomized by Pasteur's work (use-inspired basic research) rather than the cells epitomized by either Bohr (pure basic) or Edison (pure applied). This essay makes three points: (a) Stokes had a broader view that also considered the temporal flow between and among the different cells in his famous diagram; (b) Stokes argued against the relative valuation of either type of research (basic or applied); and (c) the learning sciences currently contain exemplars of all four of the cells in Stokes's famous 2 × 2 matrix, and this diversity has enriched the field, and can continue to do so, as long as work in Pasteur's quadrant is not viewed as the only worthwhile type of learning sciences research.

Where does research in the learning sciences lie on the scale from basic to applied? The well-informed reader may protest, "That's an ill-formulated question, because it uses an obsolete unidimensional characterization of the relation between basic and applied research." Indeed, the old view, as forcefully expressed more than 60 years ago by a committee of elite scientists commissioned by the Australian government, was that

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> it is obvious that most of the basic secrets of nature have been unraveled by men who were moved simply by intellectual curiosity, who wanted to discover new knowledge for its own sake. The application of the new knowledge usually comes later, often a good deal later; it is also usually achieved by other men, with different gifts and different interests. (Parliament of the Commonwealth of Australia, 1958, pp. 9–10)

However, 40 years later that view—of a unidirectional flow from the creation of knowledge to its application and of a distinct difference between the sets of skills and interests possessed by those engaged in basic versus applied research—was challenged by Donald Stokes (1997) in his widely cited (more than 3,000 times) monograph *Pasteur's Quadrant.*

Instead of the unidirectional model of basic to applied, Stokes proposed a very different characterization of the relationship between basic research and applied research, and he used it to explain the ways in which the perception of that relationship could have a profound impact on federal funding of scientific research in the United States. He summarized the thesis of his book in a single sentence: "The belief that the goals of understanding and use are inherently in conflict, and that the categories of basic and applied research are necessarily separate, is itself in

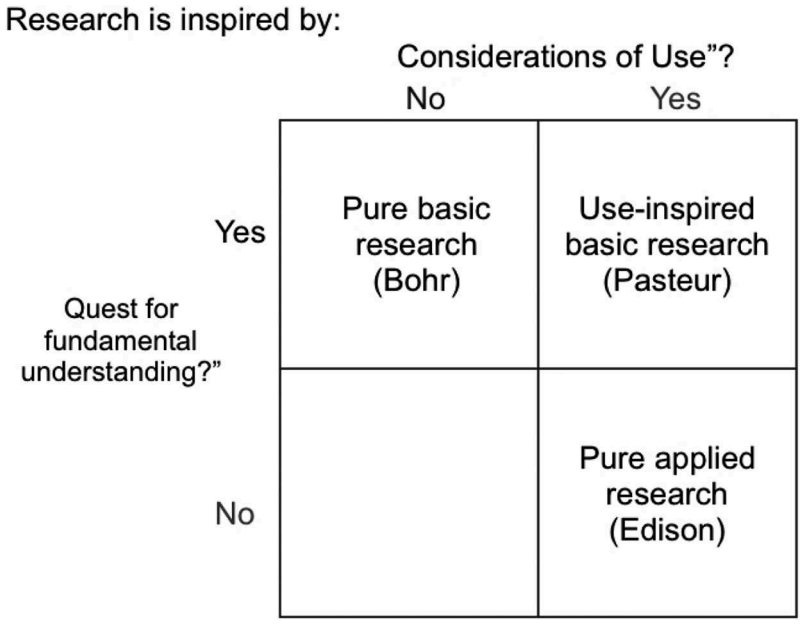

FIGURE 1 Quadrant model of scientific research (Figure caption and diagram are identical to Stokes, 1997, Fig. 3-5. Reprinted with permission of Brookings Institute).

tension with the actual experience of science" (Stokes, 1997, p. 12). Stokes's innovative characterization is captured—but only partially—in his iconic four-celled table reprinted here as Figure 1. Among the vast variety of researchers who have commented on Stokes's view are several learning scientists who publish not only in this journal (e.g., Kelly, 2004; O'Mahony et al., 2012; Sandoval, 2014; Sommerhoff et al., 2018) but also in other journals related to the learning sciences, such as *Educational Researcher* (Anderson & Shattuck, 2012). Such references invariably allude to Figure 1, with pride of place being assigned to the upper right quadrant: Pasteur's.

But there is another much more important diagram in Stokes's book, reproduced here as Figure 2. The aim of this commentary is to argue that Figure 2 better illustrates the core of Stokes's thesis about the relation between basic and applied research, even though Figure 1 is much better known, albeit commonly misunderstood and occasionally distorted. I also argue that Figure 2 offers a richer and more nuanced way to understand the relation between basic and applied research in the learning sciences.

So let us take these two figures in sequence. Stokes's diagram with the three labeled quadrants is reproduced here (see Figure 1) exactly as it appears in his book. (I will say something about the fourth, empty, quadrant later in this essay.) One subtle but important aspect of the diagram is that Stokes did not include any directional arrows in it flowing upward and rightward from the origin.

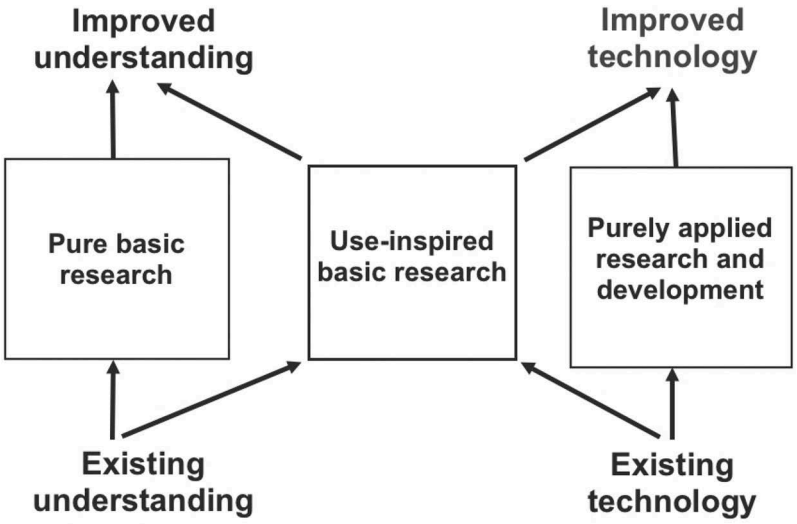

FIGURE 2 A revised dynamic model (Figure caption and diagram are identical to Stokes, 1997, Fig. 3-7. Reprinted with permission of Brookings Institute).

Nevertheless, such arrows are often added in papers that cite Stokes (cf. the version of Figure 1 that appears in a report from the National Research Council [2010]; in a recent blog post [Cantrill, 2013]; in an analysis of evidence-based practice [Smith, Schmidt, Edelen-Smith, & Cook, 2013]; and in a defense of basic research [Dudley, 2013]). This addition to Stokes's Figure 1 suggests a preferred flow resulting from the addition of the two vectors, converging on Pasteur's quadrant as a universally desirable destination for all research endeavors.

But Stokes included no such arrows in Figure 1. Their absence is crucial because, contrary to the almost universal interpretation of Stokes's work (at least in the psychological and educational literature with which I am most familiar), Stokes did not argue for a preferred temporal flow that converges in Pasteur's quadrant. In fact, Figure 1 is silent on Stokes's view of the temporal relation among the quadrants, although that relation is the whole point of his book. The task falls to another crucial but rarely cited diagram just 15 pages later (see Figure 2).

Stokes was interested in the actual temporal orderings among the three different categories of research because—having looked carefully at the historical record of the relation between science and technology—his goal was to refute the widely accepted view at the time of his writing, expressed in the opening quotation above, that there is a unidirectional flow from basic to applied research.

However, he did not argue for the primacy of Pasteur's quadrant over Bohr's or Edison's. He did not suggest that we should all aspire to work in Pasteur's quadrant. He did not recommend that government funding should privilege work aiming or claiming to fit neatly into it. To the contrary, Stokes's message was more complex and nuanced: (a) There are two kinds of fundamental *inspirations* (his terminology) for research: one is a quest for understanding and the other is consideration of use; and (b) research that has either of these inspirations in isolation might lead to more—similarly inspired—research (the vertical arrows in Figure 2) or to research in Pasteur's quadrant (the diagonals), but that research might then lead back to basic research or to applied research. That is, Stokes viewed a research universe in which pure applied research might ultimately contribute to fundamental knowledge or pure basic research might eventuate in a practical outcome. Note that they might traverse or terminate in Pasteur's quadrant, but they need not.

The multiple paths depicted in the temporal flow from the bottom to the top of Figure 2 ably convey this message. For example, the path from the lower left to the upper right of Figure 2 could characterize solid state physics research eventuating in the design and manufacture of your cell phone, whereas the path from the lower right to the upper left could indicate the way in which issues and challenges inspired by problems arising from the creation of Edison's power networks evolved into

some highly abstract (and basic) mathematical and computer science theories of network complexity. (These two examples are mine, not Stokes's.)

In his thoughtful commentary in a special issue of this journal, Greeno (2016) reviewed a set of articles on design-based research and cultural-historical theories of learning, and he appeared to credit each of them as legitimate residents of Pasteur's quadrant. Similarly, Kolodner (2004, p. 42), argued that "learning sciences is a design science, an integration science, a socio-cognitive science, a descriptive science, and an experimental science, all carried out in Pasteur's Quadrant." However, I believe that Greeno's gracious effort to commend all of the authors of those *Journal of the Learning Sciences* articles for working in Pasteur's quadrant, as well as Kolodner's sweeping assertion that all of the learning sciences reside there, (a) misinterpret Stokes's intention and (b) implicitly (in Greeno's case) and explicitly (in Kolodner's) undervalue learning sciences research with goals that happen to reside primarily in other quadrants of Stokes's diagram.

These learning scientists are certainly not alone in this. Indeed, my own perusal of the literature—admittedly not exhaustive, given the many citations of Stokes's book—suggests that the overwhelming majority of papers that allude to Pasteur's quadrant similarly misinterpret it. For example, Anderson and Shattuck (2012), in their characterization of the merits and promise of design-based research, asserted, "In many ways, [design-based research] is the educational instantiation of Stokes's *most productive* fourth quadrant, which maximizes both generalization and insight with the production of practical applications" (pp. 17–18, emphasis added). The point of this commentary is to clarify Stokes's message and to reflect on the implications of the widespread misrepresentation of his analyses and recommendations.

As these examples show, the nearly universal lack of attention to Stokes's temporal flow diagram (see Figure 2 in this article) has resulted in a distorted interpretation of Stokes: an interpretation that privileges Pasteur's quadrant as the sweet spot for which all learning scientists should aim in planning and justifying their research endeavors. For example, McCall and Green (2004, p. 4) lamented, "Researchers are currently being pressured to contribute both to theory and to societal improvement." A particularly draconian example of this (mistaken) normative interpretation of Pasteur's quadrant argues that

> faculty must be interested *both* in a quest for fundamental understanding *and* in application.… Frankly speaking, faculty who desire to pursue knowledge without consideration of use (Bohr's quadrant) or who pursue use without knowledge generation (Edison's quadrant) should probably not be in a professional school. (Tushman & O'Reilly, 2007, p. 773, italics in the original)

Finally, the mystery of the unnamed cell, that is, to whom, if anyone, did Stokes assign the lower left-hand quadrant of Figure 1? In fact, he did discuss some examples of research that fit there because they neither advanced basic science nor solved practical problems, but he never gave that cell a name. As he put it,

> The lower left-hand quadrant, which includes research that is inspired neither by the goal understanding nor by the goal of use, is *not* empty.… This quadrant includes research that systematically explores *particular* phenomenon without having in view either general explanatory objectives or any applied use to which the results will be put, … Research of this type maybe driven by the curiosity of the investigator about particular things, just as research in Bohr's quadrant is driven by the curiosity of the scientist about more general things. The bird watchers who are grateful for the highly systematic research on the markings and incidence of species that went into *Peterson's Guide to the Birds of North America* might want to call this Peterson's quadrant although this is too limited an example to warrant the name. (Stokes, 1997, pp. 74–75, italics in the original)

Another class of occupants for this unnamed cell would certainly include learning scientists engaged in meta-analysis of classroom practices, in assessments of the effectiveness of instructional strategies, in the early stages of development of curriculum and standards, and in a host of other research endeavors of great importance to the learning sciences. Many of these efforts do not aim to advance basic knowledge of the world, nor do they have immediate practical implications, but they certainly are very important types of learning sciences research.

Stokes did not intend to privilege any of the four quadrants. Nor should the goal of situating all of learning sciences research in Pasteur's quadrant be allowed to inadvertently distort the aims, topics, methods, and implicit—or explicit—value structure of our field. Instead, we can get on with our research with less concern for quadrant occupancy and more realistic, diverse, and productive goals.

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