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Improving the public value of science: A typology to inform discussion, design and implementation of research

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ABSTRACT

Decision makers call upon and fund science to solve urgent problems, catalyze innovation, and inform policy decisions. But the standard categories for describing, planning and assessing research, especially the persistence of "basic" and "applied," conceal much of the complexity and diversity of the contexts for conducting and using research, especially the role of knowledge users in the research process. Here we provide an entirely new typology aimed at allowing a more complete view of research activities and expectations, in order to improve deliberation and decision-making about research and its desired contribution to public values. Our multi-dimensional research typology divides research into three general activities: knowledge production, learning and engagement, and organizational and institutional processes, all of which are further subdivided into fifteen attributes. These idealized attributes are expressed in terms of a spectrum of value criteria ranging from strongly science-centric to strongly user-oriented. This enables consideration of the isolated knowledge value of science, the consideration and context of use, and the engagement of intended users. Used as a heuristic device, the typology can help inform and improve science-policy planning and decisions, aid in assessing the potential of existing projects, programs and institutions to achieve particular goals, and yield insights about the strengths and weaknesses of completed projects.

1. Introduction: the problem with science policy

1.1. The goal: producing more useful information for decision support

Society calls upon and funds natural, physical and social science to help clarify and resolve numerous problems including those related to coupled-human environmental systems, biotechnology, poverty reduction, economic development, energy independence, healthcare, etc. (America COMPETES Act, 2007; Bush, 1945; OECD, 2002). Some argue, however, that in its present form, science has not fulfilled expectations that it will serve society by responding to its needs and priorities (Kitcher, 2003; Dilling and Lemos, 2011; Sarewitz and Pielke, 2007). Decision makers need useful information to help inform solutions to these problems, information that educates, but also expands alternatives, clarifies choices, and aids in formulating and implementing policy decisions (Sarewitz and Pielke, 2007). Useful information must be salient and relevant to the problem, credible and of high quality, and legitimate, in that users believe that the information was produced without political suasion or bias (Cash et al., 2002). Producing useful information to inform policy also requires iterative engagement between producers and users (Sarkki et al., 2015; Lemos and Morehouse, 2005). One way to facilitate the production of useful information is to give engaged and knowledgeable stakeholders a larger role in shaping scientific research agendas (Lemos et al., 2012; Simpson et al., 2016; Dilling et al., 2015; Lackstrom et al., 2014; NRC, 2009). In the U.S., this insight has now been explicitly endorsed at the highest levels of national science-policy making. In its annual research and development priorities memo for 2017 (Donovan and Holdren, 2015), the

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Directors of the Executive Office of Science and Technology Policy and the Office of Management and Budget state, "In order to maximize the societal benefits of R&D investments, research planning and design should be guided by stakeholder and user engagement." Yet this call merely formalizes a long-standing recognition among science policy scholars and practitioners alike that the public value of research activities may often be enhanced through various types of stakeholder guidance (McNie, 2007).

How, then, should science-policy decision makers develop, implement, and assess the processes necessary to achieve such guidance? The dominant (and much debated) basic-versus-applied paradigm addresses knowledge generation, but does not speak to the multiple and complex roles that stakeholders may play in influencing knowledge generation and use. Thus, the basic-versus-applied paradigm limits recognition of science policy processes that may seek to address both knowledge generation and "stakeholder and user engagement," and it also limits comparison between science policy processes. The typology presented herein is a systematic framework for such comparison.

This paper introduces a new, multi-dimensional typology that describes three activities and related attributes that together can help inform the design, deliberation, implementation and evaluation of research. The activities and attributes introduced in this paper are idealized and intended to be heuristics. In reality the boundaries between different activities and attributes are fuzzy, with substantial 'gray areas' between them. Clarifying and characterizing types of research is important because such definitions can 'stabilize expectations' and support 'unquestioned assumptions', that influence science-policy funding and support (Calvert, 2006; Gieryn, 1999; Pielke, 2012). Application of this typology may help improve science-policy decisions by revealing the ways in which science programs may or may not be appropriately reconciled with the problem context they are supposed to address.

1.2. The problem with existing science policy

Producing useful scientific information is difficult. The worlds of science and society are far apart culturally and epistemologically, and thus directing interaction between them is challenging (McNie, 2007). Basic and applied research approaches, detached from users' needs and values, fail to adequately address the inherent uncertainties in the "problem-solving work itself" (Funtowicz and Ravetz, 1993, p. 740). Nor do these research approaches adequately integrate knowledge from multiple disciplines, cultural contexts, or the physical, natural and social sciences together. Although improving, we still have a poor understanding of how useful information is incorporated into the decision-making process (Eden, 2011; NRC, 2006). Many scientists believe their research outputs are inherently valuable to aid in learning or effective action, yet, research shows that such value is not inevitably achieved (Kropp and Wagner, 2010).

At the heart of the problem are current science policies that favor basic and applied research approaches which alone are inadequate to address the growing complexity of problems we seek to solve and simply reinforce a structural gap between the "production and use of scientific information" (Kirchhoff et al., 2013, p. 407; see Sarewitz and Pielke, 2007). Science-policy decision makers often respond to calls for more useful information by funding more science using the same basic and applied approaches. This may result in more credible and high quality information, but not necessarily useful information, resulting in missed opportunities of reconciling the supply of scientific information with the capabilities, demands, and needs of users (NRC, 2006; Sarewitz and Pielke, 2007) (See Fig. 1).

Over two dozen different terms describing scientific research have been described or adopted by the National Science Foundation, National Science Board, Office of Management and Budget,

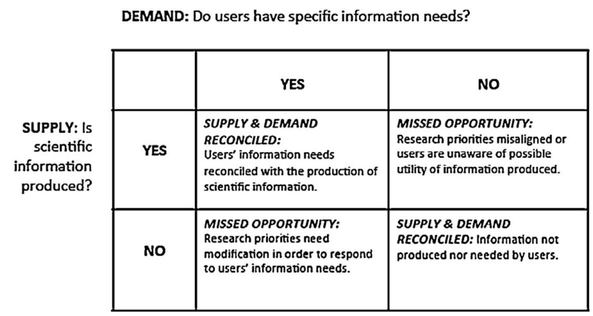

Fig. 1. Missed opportunity matrix.
Adapted from Sarewitz and Pielke (2007).

Organization for Economic Cooperation and Development (OECD), science-policy researchers and others during this century and last (see Table 1). Research types have been defined by many variables, although the differences between many types are often minor or semantic (Calvert, 2006; Stokes, 1997).

Indeed, OECD, which includes the world's most research-active nations, through it's Frascati manual, is almost militant in the narrowness of its definition of research. The latest (2002) version of the manual asserts: "The basic criteria for distinguishing R&D from related activities is the presence in R&D of an appreciable element of novelty and the resolution of scientific and/or technological uncertainty, i.e., *when the solution to a problem is not readily apparent to someone familiar with the basic stock of common knowledge and techniques for the area concerned*" [OECD, 2002 p. 34; emphasis added]. Such a definition eliminates even the possibility of incorporating the influence of knowledge use and knowledge on research processes by limiting research activities to those involving only technical subject area experts (i.e., scientific researchers).

Today, basic and applied research approaches have become epistemic norms in the science community, and as a result, most research types can be classified as basic or applied. These approaches are defined mostly by only two qualities: the motivation for research (fundamental discovery vs. application of knowledge) and temporal delay to application of research results.

Many practitioners and scholars of science policy have come to recognize that the basic/applied dichotomy may conceal as much as it reveals. For example, in Stokes' well-known conception of use-inspired research, he added to the standard dichotomy a new dimension (Pasteur's Quadrant) that accommodated the recognition that research, whether basic or applied, is commonly influenced by considerations of use (1997). Little to no progress has been made in translating such insights into criteria for research design, which is an ongoing and iterative process that implies not only the design of particular science study, project, or program, but its ongoing management and evaluation. Even Stokes failed to consider the role of users themselves. The character of scientific knowledge, the intended use of science, and the role of users in the research process are all pertinent to appropriate research design.

Moreover, public investments in science have always been significantly justified by the promise and expectation that more research—both basic and applied—would respond to problems

Table 1
Standard research approaches.

Ad hoc	Curiosity-driven	Jeffersonian	Pure-basic
Applied	Curiosity-oriented	Mode 1	Purposive-basic
Background	Development	Mission-oriented	Strategic
Baconian	Directed	Newtonian	Tactical
Basic	Experimental	Normal science	Translational
Clinical	Free basic	Oriented-basic	Uncommitted
Committed	Fundamental	Pure	Use-inspired