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Gendered Science in the 21st Century: Productivity Puzzle 2.0?

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ABSTRACT
The notion of the 'productivity puzzle', referring particularly to gender disparities in science and technology publication rates, raises a variety of critical issues for understanding related workforce development and capacity. However, such issues typically are framed relative to an increasingly outdated cultural and technological landscape in which scientific productivity is viewed principally as an outcome. We argue instead that characterizing scientific productivity as a multifaceted, dynamic, highly networked, and interactive process, rather than just an outcome, might provide greater insight into the gendered nature of science and lead to a re-framing of the gender-differentiated productivity puzzle. By rethinking how we engage related questions, we might gain ground on explaining and unraveling the productivity puzzle in ways that will benefit the scientific enterprise and society in general.

KEYWORDS
scientific productivity; STEM; gender; productivity puzzle

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The 'productivity puzzle', as it was characterized nearly three decades ago by Cole and Zuckerman (1984), remains a prominent matter on policy agendas and in scientific inquiry more generally. Referring to the tendency for women to publish at lesser rates than men, as in some science, technology, engineering, and mathematics (STEM) fields, the productivity puzzle has been found in many related studies. Why is this? More to the point, under what circumstances are female deficits in productivity seen? These same basic questions continue to be raised in the literature today. Yet, while they certainly address critical issues for understanding STEM workforce development and capacity, they also continue to be framed relative to an increasingly outdated cultural and technological landscape, and one in which scientific productivity is viewed principally as an outcome.

Peer-reviewed publications have been the conventional basis for many of the indicators used to characterize scientific productivity and, especially, to assess performance within the halls of academia. Indeed, 'publish or perish' is a mantra that has long held sway in the institutional milieu, and counts of articles are a paramount consideration in establishing the status and rank of individuals within scientific communities. Moreover, while the impact of publications is recognized as a crucial consideration when assessing scientific productivity, many of the indicators that are typically used to measure impact are themselves based on publications. In particular, measures of citation impact, journal quality, and even contributions to research and knowledge creation are all based on published articles. Publications are even a prime consideration when awarding grants and contracts, which in turn can affect publication outcomes.

This scientific context is changing. Through the latest technological innovations, especially those embedded in the Internet and the digital domain more generally, we now have new ways to do science — new ways to collaborate, new ways to communicate findings, and even new ways to conduct peer reviews (LSE Public Policy Group, 2011). Online social networks, whether mainstream (e.g., Facebook, Twitter, etc.) or targeted specifically to scientists (e.g., academia.edu, VIVO, etc.), provide a new mechanism for scholars and researchers to meet and exchange ideas. In contrast to traditional scientific communities, especially those based primarily on face-to-face contact, Internet forums provide a much easier mechanism for the diffusion of knowledge and for scientists to communicate in time and space (Ginsparg, 2011). In addition to these digital networks, tools like blogs and wikis are increasingly popular means for disseminating research findings. Through the ability to comment and evaluate the information distributed via these forums, there is a newly evolving type of peer review where literally anyone in the world can critically assess the ideas and findings of an individual or organization. Some have referred to this emergent environment as Science 2.0 (Tapscott and Williams, 2008). With collective intelligence and sharing as prominent characteristics of the Science 2.0 world, there has been an explosion in the amount and type of data that are publicly available on the Internet and through web-based applications. Further, the expanded availability of software online allows for sophisticated analysis that, previously, only highly skilled information or computer scientists could access or know how to use.

This Science 2.0 environment also renders notions of scientific productivity much more complex than traditional notions based on stock indicators like publication counts. In the face of new dynamic and interactive ways to conduct, disseminate, and evaluate research, productivity would be more aptly framed and measured as a *process* rather than an outcome (McNeely and Schintler, 2010). Moreover, given the complexity attending the conduct of science and innovation today, the life of an idea — from its 'eureka' moment, through its growth, development, and diffusion — is rarely the product of a single individual. Rather, it results from the influence of a collection of people (Rycroft and Kash, 1999). This was the point made by Gladwell (2002) when, using concepts from epidemiology, he argued that three types of individuals — connectors, mavens, and salespeople — are critical in facilitating a tipping point, such as the sudden and widespread adoption of an idea or technology. In social network terms, connectors are individuals who bridge cliques and often are the most centrally positioned within the networks to which they belong. Mavens and salespeople also are made integral to the process by communicating and synthesizing scientific knowledge and in presenting new and compelling ideas upon which further productivity is based.

How does this all relate back to the productivity puzzle? It points to a number of fundamental issues for understanding the situation and raises a number of intriguing and critical questions — and, perhaps, it also points to a need to re-conceptualize the puzzle itself. Thus, for example, access to and position within networks have been identified in the literature as critical indicators of scientific productivity and, in considering effects on related outcomes, women have been found to be disadvantaged in this regard (e.g., as in collaboration networks) (NRC, 2009; Fox, 1991; Steffen-Fluhr, 2006). Also, as suggested by recent studies showing that gender differences in spatial and other outcomes can be largely attributed to nurture and education (Hoffman, Gneezy, & List, 2011), the process from which the puzzling outcomes result must be taken seriously if we are to truly understand related productivity levels. This is especially notable in light of the gendered 'impact enigma' in some STEM fields, in which women's publications, although fewer, have been found to be more highly cited than those of their male counterparts — even when the women occupy more 'marginal' professional positions (Long, 1992; Symonds, 2007). Citations are the conventional metric for determining impact and, while such findings have yet to be explained, they lead to challenges and questions about the reliance on sheer mass of publications as the reigning measure of productivity (Francl, 2005).

If scientific productivity is recognized as a process in which collaboration and collective intelligence (and even open and ongoing peer review) are inherent features, what are the implications for understanding and evaluating scientific impact and contribution? Would this offer a more realistic view of individual contributions to scientific productivity in today's world? How can we develop measures of scientific productivity that are inclusive of traditional publications, but that also reflect the contributions to science made through blogs, wikis, and other newer forms of information and knowledge dissemination? What would be the related implications for performance assessment (e.g., in academic tenure and promotion cases)? Would female participation and productivity rates and patterns be differently characterized within the process? What roles and positions do women occupy in scientific networks and communities and what do those roles and positions mean in terms of the productivity process? Are they connectors, mavens, or salespeople, and under what circumstances are they found in these roles?

If we characterize scientific productivity in light of such complexities — as a multifaceted, dynamic, highly networked, and interactive process rather than just an outcome (e.g., number of publications) — to what extent might we gain ground on explaining and unraveling the productivity puzzle?

Furthermore, are the tools and opportunities that define Science 2.0 creating an environment that facilitates and is more favorable for women (and, for that matter, everyone) in terms of broadening participation and contributing to science? Will we, over time, find different productivity outcomes (even in conventional terms) for women when defined and assessed relative to the broader productive process and affiliated social dynamics? Will Science 2.0 change the gendered nature of science?

It might well be that the trend is toward a more horizontal and egalitarian science community, as suggested by Tapscott and Williams (2008, p. 157):

> Just as collaborative tools and applications are reshaping enterprises, the new Web will forever change the way scientists publish, manage data, and collaborate across institutional boundaries. The walls dividing institutions will crumble, and open scientific networks will emerge in their place. All the world's scientific data and research will at last be available to every single researcher — gratis — without prejudice.

However, as they also note, such an environment may not be entirely possible. Despite democratizing potential and goals (Ginsparg, 2011), gatekeepers and hierarchical structures to some extent are inevitable in the process. It would be naïve to think otherwise. In other words, a vertical structure, within which some individuals are more central or have more influence and control over the creation and flow of knowledge, seems unavoidable. The extent to which such positioning would remain gender-specified and ascriptively stratified is the overriding question. These structural relations and dynamics reflect networked disparities that, frankly, can be expected to continue, especially in light of the increasing commodification and monetization of information, both of and on the digital terrain. Moreover, contextual and other factors operate — directly or indirectly, intentionally or unintentionally — to restrict the access and participation of women (and of others who are underrepresented in STEM), thus creating and perpetuating what we have called the 'digital knowledge *network* divide' (or DKND) (Schintler, McNeely, & Kulkarni, 2011). However, irrespective of outcome, a deeper understanding of productivity as a dynamic process is fundamental to assessing this situation and recognizing both challenges and possibilities for broadening participation and increasing contributions to the STEM enterprise in general.

That is, more than ever before, we might beneficially complicate the notion and assessment of productivity by explicitly incorporating the related process to gain currency on the situation in this transformed and transforming reality. Accordingly, to the extent that this remains a *gendered process* even in this new technological and cultural environment, should we perhaps re-conceptualize gender differences in science and re-frame the gendered paradox as the 'Productivity Puzzle 2.0'?

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