The Social Science and Engineering of Research Practice

Physical scientists have a huge opportunity to improve their research practice through systematic application of the emerging social science of creativity and research.

T.B. Odumosu, G.W. Crabtree, V. Narayanamurti, J.Y. Tsao

The verdict is in

The verdict is in: the methods of science can significantly enhance the effectiveness of creative teams. Just ask employers like Google and Facebook who are applying ideas from the social sciences to improve the performance of their organizations.[1] Over the last few decades, social scientists, including psychologists, sociologists and anthropologists, have made important strides in developing a scientific understanding of how creative individuals and creative communities operate.[2]

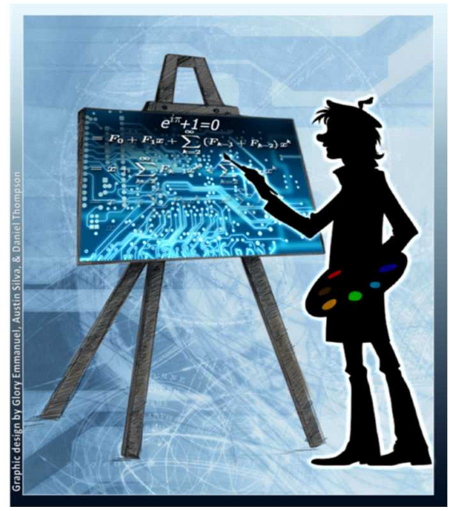
Why not apply these social scientific insights into the dynamics of creativity to one of the most creative of human endeavors – the production of scientific and technological knowledge? We tend to pursue science and technology by the seat of our pants; surely there is room for improvement!

Recently, Sandia National Laboratories sponsored an Art & Science of Science & Technology Forum & Roundtable[3] which brought together distinguished practitioners of the art of research in the physical sciences with experts in the social science of creativity and research. The meeting was truly a robust exchange of ideas with much learning and teaching on both sides. The over-riding sense at its conclusion, and the main message of this article, is that *it is time for physical scientists to take seriously the idea that their research practice can be improved through systematic application of the emerging social science of creativity, research, and the institutional cultures that nurture them.*

This idea is not new. The idea of utilizing scientific methods to study and improve creative practice is one that has been slowly but surely gaining steam.

One example: the science policy community has taken seriously the notion that science policy itself needs to be firmly anchored in scientific ideas and analysis. This movement, variously described as the Science of Science Policy, has made substantial progress, particularly through NSF's Science of Science and Innovation Policy (SciSIP) program.[4] SciSIP supports the development and improvement of "models, analytical tools, data and metrics" that may be applied to decision making in science policy.

Another example: the rise of a research community within the Life Sciences devoted to the science of creative teams. The work of these scholars has led to the creation of a "cross-disciplinary field of study that aims to help maximize the efficiency and effectiveness of team-based research."[5] This movement has also gained ground,



particularly through the NIH's Science of Team Science (SciTS) program.[6]

Opportunity for the physical sciences

Similar opportunity exists for the physical sciences.

As mathematized, deep, and the object of envy as are the physical sciences, the truth is that research in the physical sciences is just as much a social enterprise and practiced just as much like an art or craft as is research in other sciences. The reality is, we don't always know why research teams are at times highly functional, enhancing individual abilities, and at other times severely dysfunctional, inhibiting individual abilities and experiencing sub-optimal performance. To be sure, successful and respected research leaders usually have a deep understanding of these matters, steeped as they are in hard-earned experience. However this understanding is intuitive, without the analytical language or toolsets necessary to decode best practices, improve and replicate

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*Figure courtesy of Glory Emmanuel, Austin Silva, Daniel Thompson, Sandia National Laboratories.

(a) Engineering & Society Department, University of Virginia, Charlottesville, VA 22904 (todumosu@virginia.edu). (b) Materials Science Division, Argonne National Laboratory, Argonne, IL 60439 (crabtree@anl.gov). (c) School of Engineering and Applied Science and Kennedy School of Government, Harvard University, Cambridge, MA 02138 (Venky@seas.harvard.edu). (d) Physical, Chemical and Nano Sciences Center, Sandia National Laboratories, Albuquerque NM 87185 (jytsao@sandia.gov).

[1] See, e.g., L. Bock, "Work rules" (Twelve, 2015).

[2] See, e.g.: G.J. Feist GJ, "The psychology of science and the origins of the scientific mind" (Yale University Press, 2008); R.K. Sawyer, "Explaining creativity: The science of human innovation" (Oxford University Press, 2011); S. Sismondo, "An introduction to science and technology studies" (John Wiley & Sons, 2011).

[3] http://belfercenter.ksg.harvard.edu/files/asst-web-final.pdf.

[4] K.H. Fealing, J.I. Lane, J.H. Marburger, S.S. Shipp, Eds., "The science of science policy: A handbook" (Stanford University Press, 2011). http://www.scienceofsciencepolicy.net/SciSIPCentral.

[5] This particular community is a fascinating case. On the one hand, the Life Sciences are well *behind* the physical sciences in the establishment of the primacy of observation and experiment (perhaps due to the complexity of determining cause and effect in clinical practice). On the other hand, the Life Sciences are well *ahead* of the physical sciences in embracing "evidence-based" social sciences to facilitate and accelerate interdisciplinary and translational research teams, perhaps because the translational gap between science and clinical practice is so wide and difficult to bridge.

[6] K. Börner, N. Contractor, H.J. Falk-Krzeskinski, S.M. Fiore, K.L. Hall, J. Keyton, B. Spring, D. Stokols, W. Trochim, B. Uzzi (2010) A multi-level systems perspective for the science of team science. Science Translational Medicine 2(49):49cm24-49cm24. See also Nancy J. Cooke and Margaret L. Hilton, Eds., (Enhancing the Effectiveness of Team Science" (The National Academies Press, 2015). http://www.scienceofteamscience.org/.

such practices, and then systematically raise the bar everywhere else.

The physical sciences are hardly over with – many of our most pressing planetary-scale problems, from global warming to moving the world towards a sustainable energy diet, require solutions rooted in the physical sciences. These problems, like those in the life sciences, will be tackled by interdisciplinary and translational teams whose human complexity, subtlety and productivity will only be optimized by insights from *outside* the domain of the physical sciences.[7]

The social sciences are not only developing analytical language and toolsets for qualitatively understanding creativity and research, they are poised to begin quantifying these through social analytics at all levels of the research enterprise. For example, at the conclusion of the Sandia Forum & Roundtable, among the concepts believed ripe for exploitation was that of divergent and convergent thinking.[8] Divergent thinking is the generation of new dissimilar ideas, while convergent thinking is the filtering, refining and retention of the most useful of those ideas. Both processes are necessary in research. The best research often begins with divergent thinking and then switches to convergent thinking – as the best ideas float to the top. Both are moderated and in some cases severely compromised by human cognitive and social predispositions. Divergent thinking can be compromised by idea fixation — an adherence to existing ideas that limits the ability to recognize and embrace new ideas;[9] while convergent thinking can be compromised by groupthink, in which a desire for social consensus interferes with selecting the best ideas.[10] Social and data analytics can in principle measure the degree to which research teams are engaging in behaviors considered essential to both divergent thinking (e.g., exposure to ideas off the team's center of gravity) and convergent thinking (e.g., deep technical debate).

Our biggest challenge is ourselves

Given all this, one might expect that the physical sciences, which have time and again embraced revolutionary new ideas that have re-shaped our world, would embrace the new knowledge and tools associated with the social science of creativity and research. This has not been the case. Prior engagements between the social and physical sciences have even been sometimes acrimonious (though even these tense engagements led to some productive insights).[11]

Why have physical scientists not begun to harness social science to improve how they do research? From our own perspective as physical scientists, a few likely reasons suggest themselves.

First, we have had a phenomenal record of success without help from social science. The physical sciences have remade the world many times over in the past centuries. Why argue with success – why not just leave things as they are and continue to remake the world?

Second, it could be a simple matter of pride. Physical scientists are used to being *the* scientists, with physical phenomena being the object of study. Working with social scientists may require us to become uncomfortable objects of study. Worse, many physical scientists think of social science as a lesser endeavor, with the implication that social scientists have very little to offer.

Finally, we may desire that the artistry of the research endeavor not be unmasked lest doing so spoils its allure. What happens to the thrill of discovery or invention if the researcher has been assisted in its accomplishment via a social science intervention?

But the stakes are high

Despite these challenges, we believe the stakes are too high not to try to address them. As mentioned above, many of our most pressing planetary-scale problems are physical-science based. Formal, U.S.-government-funded physical-science-and-engineering research in FY2012 was $17.8B/year.[12] Even a relatively small productivity increase in physical-science-and-engineering research practice could have significant impact. Additionally, because the product of research, knowledge, accumulates and compounds, the long-term societal gain are even larger.

Moreover, if the physical sciences adopt short feedback cycles for integrating the new social science knowledge and tools into daily practice, it will not be so much a "study" by an outsider as it would be a process of self-reflection and improvement using sound science as the basis for internal decision making. Many of the current standard metrics of research effectiveness (such as the H-index) suffer from short-comings, providing ample reason to try something new, and to engage with our colleagues in the social sciences in a joint effort to understand and improve our own research practice at a more deeply critical, reflective, and quantitatively analytical level.

Indeed, after our experience at the Art & Science of Science & Technology Forum & Roundtable mentioned above, one of us (GC) introduced the concepts of divergent and convergent thinking into the strategic language of the Department of Energy's Joint Center for Energy Storage Research (JCESR).[13] This Center, devoted to transformational next generation energy storage technology and spanning 14 institutions and 160 people, must engage in effective divergent thinking to identify new technology directions followed by equally effective convergent thinking to develop the most promising ones. Similarly, another of us (JYT) has begun championing the use of social analytics to measure divergent and convergent thinking in research teams at Sandia National Laboratories.

We encourage physical scientists to explore this rich new body of scholarship and to be receptive to the broad possibilities and advantages to be gained from engaging with the social sciences.

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[7] See, e.g.,: M.C. Binz-Scharf, Y. Kalish, L. Paik, "Making Science: New Generations of Collaborative Knowledge Production," American Behavioral Scientist (November 20, 2014); Jones, Benjamin F., Stefan Wuchty, and Brian Uzzi. "Multi-University Research Teams: Shifting Impact, Geography, and Stratification in," Science 322, no. 5905 (November 21, 2008): 1259–62; S. Jeong, Jae Young Choi. "Collaborative Research for Academic Knowledge Creation: How Team Characteristics, Motivation, and Processes Influence Research Impact," Science and Public Policy, October 20, 2014.

[8] A. Cropley (2006) In praise of convergent thinking. Creativity research journal 18(3):391-404.

[9] For example, students asked to design a new coffee grinder, when asked not to employ a certain design, cannot help but anchor their thinking around the exact design they have been told to ignore. J.S. Linsey, I. Tseng, K. Fu, J. Cagan, K.L. Wood, C. Schunn (2010) A study of design fixation, its mitigation and perception in engineering design faculty. Journal of Mechanical Design 132(4):041003.

[10] J. Lehrer, "Groupthink: The Brainstorming Myth," The New Yorker (January 20, 2012).

[11] The so-called "Science Wars" were a particularly un-productive episode in the interaction between social and physical scientists: http://en.wikipedia.org/wiki/Science_wars.

[12] National Science Foundation, "Federal Funds for Research and Development: Fiscal Years 2012-2014" (September, 2014).

[13] http://www.jcesr.org/.